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SULFATED ALCOHOLS IN INSECTICIDES

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Sulfated alcohols, which have been developed in recent years as detergents, have properties which indicate that they may have uses in insect control work. Some of their characteristics are:

1. They are good wetting and sudsing agents.
2. They may be used in acid solutions.
3. Aqueous solutions are stable in alkalies.
4. They are compatible with hard water.

In consideration of these apparently favorable characteristics, preliminary studies have been made to ascertain their value as toxic agents for insects; as emulsifying agents for oils and other insecticides; as dispersing and carrying agents for certain insecticides, especially those that deteriorate in alkaline solutions; as wetting agents for alkaline as well as acid sprays; and as an aid in removal of the arsenical and lead residues on sprayed fruit.

The following sulfated alcohols[2] were used: Sodium lauryl sulfate, sodium octadecyl sulfate, sodium oleyl sulfate and sodium oleyl sulfate special.[3] The alcohols from which the compounds are derived are not pure. They are commercial types containing small amounts of other alcohols in the series. They have been standardized with sodium sulfate and the percentages of active material they contained was approximately as follows: Sodium lauryl sulfate 50 per cent; sodium octadecyl sulfate 60 per cent; sodium oleyl sulfate 28 per cent; and sodium oleyl sulfate special 45 per cent.

[1]Joint authors.
[2]Samples and information were furnished by E. I. du Pont de Nemours & Company.
[3]Sodium oleyl sulfate and sodium oleyl sulfate special are both derived from oleyl alcohol, but sulfated under different conditions.

Based on the percentage of active ingredients, preliminary tests, using grasshoppers as the test animals, showed that while all the materials have some toxicity, sodium lauryl sulfate and sodium oleyl sulfate special were the most toxic. These compared favorably with neutral potassium cocoanut fatty acid soap (Table 1). This same rating prevailed when emulsifying and wetting properties were considered.

TABLE 1. COMPARATIVE TOXICITY OF SULFATED ALCOHOLS, SULFATED OLEYL ACETATE AND POTASSIUM COCOANUT FATTY ACID SOAP TO GRASSHOPPERS, *Melanoplus femur-rubrum*—TREATED BY DIPPING FOR FIFTEEN SECONDS

Material	Percentage of active ingredient	Number tests	Number treated	Percentage dead
Sodium lauryl sulfate	1.00	1	10	100.00
	.50	4	40	95.00
	.25	5	50	90.00
Sodium oleyl sulfate	1.00	2	20	90.00
	.50	3	30	70.00
	.28	5	50	60.00
Octadecyl sulfate	1.00	1	11	90.00
	.60	7	70	34.20
	.30	3	30	3.30
Sodium oleyl sulfate special	1.00	1	10	100.00
	.50	2	20	80.00
	.25	2	20	65.00
Soap	1.00	5	50	92.00
	.50	4	40	82.50
	.25	2	20	60.00
Sodium sulfate	1.00	1	10	10.00
Water	—	5	50	2.00

In order of toxicity, they are rated as follows: sodium lauryl sulfate, sodium oleyl sulfate special, soap, sodium oleyl sulfate, and octadecyl sulfate.

A spray of sodium lauryl sulfate at a dilution of 1 per cent of the commercial product or 0.5 per cent of active ingredient gave a kill on cabbage aphis varying from 92 to 98.2 per cent, and on red spider the kill was 94 per cent. At a dilution of 0.5 per cent of the commercial or 0.25 per cent of active ingredient, the kill was 71 per cent for red spider and 20.5 per cent for the cabbage aphis. Sodium oleyl sulfate special at 1 per cent solution of the commercial product killed 92.1 per cent of cabbage aphis.

Plants vary in their susceptibility to injury from sulfated alcohols. Snapdragons will withstand a 1 per cent solution of the commercial product of sodium lauryl sulfate, while a solution containing more than .25 per cent will injure chrysanthemums. Lantana is injured by .5 per cent solution. Sodium oleyl sulfate special is slightly more injurious to foliage than sodium lauryl sulfate. These conditions indicate that sulfated alcohols cannot be used alone as insecticides until the factor or factors causing plant injury are discovered and reduced.

As a carrier for other insecticides, some of the sulfated alcohols appear to have potentialities. With nicotine sulfate 40 per cent added at the rate of 1 part to 1000 parts, the following results were obtained with cabbage aphids:

	Per cent kill
Sodium oleyl sulfate .06 per cent commercial product	25
Sodium lauryl sulfate .06 per cent commercial product	83
Sodium oleyl sulfate special .06 per cent commercial product	99.3
Cocoanut fatty acid soap—12 per cent actual soap	66.1
Nicotine only	17.5

Preliminary tests with solutions containing .02 per cent pyrethrins gave the following averaged kills on the Mexican mealy bug.

	Per cent kill
Sodium lauryl sulfate .25 per cent of the commercial product	62.2
Sodium lauryl sulfate .50 per cent of the commercial product	100.0
Sodium oleyl sulfate special .25 per cent of the commercial product	57.0
Sodium oleyl sulfate special .50 per cent of the commercial product	100.0
Sodium oleyl sulfate special (alone) .5 per cent of the commercial product	45.0
Sodium lauryl sulfate (alone) .25 per cent of commercial product	0
Sodium lauryl sulfate (alone) .5 per cent of commercial product	23.8
Pyrethrins alone (.02 per cent sol.)	33.3

Using grasshoppers dipped for ten seconds the addition of .01 per cent pyrethrins to a .12 per cent solution of sodium lauryl sulfate increased the average kill from either of the solutions alone from 10 per cent to 66.6 per cent. Using box elder bugs, dipped for five seconds, results as follows were obtained: Nicotine sulfate 1–500, 10 per cent dead; sodium lauryl sulfate .25 per cent (commercial product) 0 per cent dead, and sodium lauryl sulfate .25 per cent solution, plus nicotine sulfate 1–500, 75 per cent dead.

As a mosquito larvicide both sodium lauryl sulfate and sodium oleyl sulfate special at a dilution of 0.5 per cent of the active ingredients showed decided toxicity. Based on the time required to kill, the former was the more toxic. Sodium lauryl sulfate when used at the rate of 0.5 per cent in an aqueous solution of pyrethrins at the rates of 1 part to 1 million and 1 part to 5 million, increased the speed of action nearly to four times in each dilution.

Sodium oleyl sulfate special in similar tests, in addition to aqueous solutions of pyrethrins up to 1 part to 1 million, showed an increase in the speed of action of approximately two and a half times. The sodium sulphate which occurs in the commercial products did not exhibit any toxicity up to 34 minutes.

These results summarize the data for 79 tests on *Culex pipiens*.

All of the materials in this work may be used as emulsifying agents for petroleum oils, pine oils and carbon bisulphide. Sodium lauryl sulfate and sodium oleyl sulfate special are far superior at ordinary temperatures to either of the other two materials in their emulsifying properties. Sodium oleyl sulfate is superior to sodium octadecyl sulfate. Both sodium lauryl sulfate and sodium oleyl sulfate special, on the basis of active ingredients, appear to be better than potassium cocoanut fatty acid soap. Stable emulsions of petroleum oils, both sulfonated and unsulfonated, ranging from kerosene fractions to viscosity of 110 Saybolt have been made to contain 83.3 per cent oil. With sodium lauryl sulfate good emulsions can be made by using very small quantities. 100 mg. of the commercial product dissolved in 20 cc. of water will emulsify 100 cc. of oil. However, the emulsions are more easily made if 500 mg. or 1 gram are used with 20 cc. of water and 100 cc. of oil.

For emulsifying carbon bisulphide sulfated alcohols appear to be far superior to soap. The breakdown that occurs in carbon bisulphide emulsion made with soap does not occur in the emulsions made with these

materials. For carbon bisulphide the sodium oleyl sulfate special seems to be a better emulsifying agent than sodium lauryl sulfate.

In general the emulsifying properties of the several compounds are rated as follows: Sodium lauryl sulfate, sodium oleyl sulfate special, sodium oleyl sulfate and sodium octadecyl sulfate.

As wetting agents sodium lauryl sulfate and sodium oleyl sulfate special seem to have possibilities. Excellent wetting is obtained on such waxy leaves as cabbage and kohlrabi with .06 per cent concentration of the active ingredient of the materials. Table 2 gives the wettability of the various materials in comparison with soap.

TABLE 2. RELATIVE PERCENTAGES ON THE UNDER SURFACE OF LEAVES OF KOHLRABI WETTED BY VARIOUS CONCENTRATIONS OF SULFATED ALCOHOLS AND SULFATED OLEYL ACETATE BY DIPPING

Material	Active ingredient Concentration of Solution			
	.25%	.12%	.06%	.03%
Sodium lauryl sulfate	100%	100%	75–90	25–60
Sodium olyel sulfate	50–100	20–50	10–30	5–20
Sodium octadecyl sulfate	5–25	5–10	0–5	0–5
Sodium oleyl sulfate special	100	100	75–100	60–90
Soap (Potassium cocoanut fatty acid)	100	50–100	0–10	0–5
Water	0–5			

A wettable sulfur is procured by mixing 1 part, by weight, of sodium lauryl sulfate with 100 parts, by weight, of sulfur. All of the sulfated alcohols appear to be compatible with lime sulfur and arsenate of lead.

With the advent of fruit washing to remove residues from sprayed fruit there has been a distinct need for some material for use in the acid solution to aid in removing residues. Because of its detergent qualities in cold water and its emulsifying properties sodium lauryl sulfate was tested for this purpose. One pound of the compound to 100 gallons of cold water containing 1 per cent HCl acid removed from 86 to 89 per cent of the lead and from 85 to 89 per cent of the arsenic while the acid solution alone removed from 63 to 75 per cent of the lead and from 63 to 70 per cent of the arsenic.

THE ACCUMULATIVE EFFECT OF OIL SPRAYS ON APPLE TREES

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During the past 15 years numerous papers have appeared treating on the effects of oil sprays on deciduous fruit trees. Most of these papers refer to the immediate effect following certain types of oil sprays. The accumulative effect of yearly applications of oils has been mentioned but not studied over long periods. The following study was started five and ten years ago to determine the effect of annual spraying with oils on the growth of apple trees.

The results of a ten year test are given in Table 1. Starting with trees 7 to 9 years of age they have received each year the same dormant spray

both in formulae and concentration. The trees listed in Item 1 received an application of 2 per cent emulsion; Item 2, 8 per cent emulsion; Item 3, untreated controls.

TABLE 1. GROWTH FOLLOWING TEN ANNUAL DORMANT SPRAYS ON JONATHAN, GRIMES, AND DELICIOUS APPLES OVER THE 9 TO 19TH YEAR PERIOD OF THEIR DEVELOPMENT

Item No.	Spray	% conc.	No. of trees	Average yearly growth of twigs 1925–1927 Length (inches)	Circum. (inches)	Bark sq. inches	Height 1934 (feet)	Percentage increase on trunk circumference 1932 to 1934
1	Miscible oil	2	7	8.58	0.719	6.15	18.5	10.1
2	Miscible oil	8	7	8.88	0.729	6.47	19.9	9.6
3	No treatment	–	6	8.64	0.709	6.12	20.3	10.2

Although the numbers of trees involved are small, measurements of growth as expressed in Table 1 do not show wide differences. Except for 3 to 4 weeks immediately following the application of dormant oil sprays, experienced horticulturists have not been able to identify the various treatments by differences in the appearance of the trees.

Although the trees are now 17 to 19 years old, they have never borne more than a very scattered crop. Both the bloom and yield records are too erratic to furnish reliable information relative to the treatments. The trees receiving 8 per cent oil spray each year have been retarded in their early season development of bloom and foliage. This retardation has been rather striking for from 3 to 7 days after growth starts. Within three weeks after growth starts, the 8 per cent oil-sprayed trees appeared normal and continued normal development throughout the season. Retardation affected the three varieties about equally. During one season in which the 8 per cent concentration was applied to Delicious in the delayed dormant stage, severe killing of lateral buds and terminal growths occurred.

In 1929 a second experiment with a larger number of trees was started on trees 7 to 11 years of age. The orchard contained Jonathan, Grimes and Delicious varieties of varying ages. A single row through the orchard constituted a test as expressed by item numbers Table 2. In this experiment the factors of, type of emulsion, degree of saturation, viscosity, type of emulsifier, season of application, stage of tree development and per cent of concentration, were involved.

Of the dormant applications, Items 1, 2, 7, 8 and 9 caused neither injury nor retardation. Item 3 noticeably retarded the foliage during two years. Item 4, which retarded leaf bud opening only one year, is of special interest from the fact that this spray was applied when the relative humidity was 90 per cent or greater, since Kelley found that under laboratory conditions boiled fish oil soap emulsions increased penetration and injury to both dormant twigs and foliage in a saturated atmosphere. Item 10 delayed leaf bud opening during two seasons in one of which the retardation was considerable. Item 5 in most cases caused slight scorching of leaf margins, dwarfing of primary leaves, and from 2 to 5 days retardation. Some of these conditions were apparent for as much as three weeks after the spray was applied. Item 6—Miscible oil at 8 per cent concentration, caused a retardation comparable with Item 2, Table 1.

TABLE 2. GROWTH OF JONATHAN, GRIMES AND DELICIOUS APPLE TREES 11 TO 17 YEARS OLD SPRAYED SINCE 1929 (5 YEARS) WITH OIL EMULSIONS OF IDENTICAL FORMULAE

Dormant One Spray Annually; Summer, 3 Sprays Annually Between June 25 and August 15. Weather Conditions Fair During Application With Exception of Item 4 in Which the Relative Humidity was 90–95 Per cent

Item No.	Type of emulsion	% saturation	Vis. sec. 100°F.	Emulsifier	Season of application	Stage of tree development	% conc.	No. trees	Ave. height 1934 (feet)	% increase in trunk circumference 1932–1934
1	Miscible	90	85	Soap	Fall	Dormant	2	11	17.2	17.5
2	Miscible	90	85	Soap	Winter	Dormant	2	11	16.6	18.5
3	Miscible	90	85	Soap	Spring	Dormant	2	12	16.7	16.5
4	Miscible	90	85	Soap	Spring	Dormant	2	12	17.6	19.0
5	Miscible	90	85	Soap	Spring	Dormant (Del.)	2	11	17.7	17.5
6	Miscible	90	85	Soap	Spring	Dormant	8	11	18.1	15.6
7	Miscible	90	235	Soap	Spring	Dormant	2	12	18.0	16.9
8	Miscible	100	60	Soap	Spring	Dormant	2	12	16.7	16.0
9	Miscible	100	85	Soap	Spring	Dormant	2	12	18.0	18.9
10	Stock	90	104	K.F.O.S.	Spring	Dormant	3	11	17.3	17.7
11	Stock	90	32	Inert	Summer	Fruit and foliage	2	11	18.3	18.4
12	Stock	90	83	Inert	Summer	Fruit and foliage	2	10	16.6	15.8
13	Stock	100	32	Inert	Summer	Fruit and foliage	2	12	17.5	17.1
14	Stock	100	83	Inert	Summer	Fruit and foliage	2	12	17.9	15.7
15	Stock	100	200	Inert	Summer	Fruit and foliage	2	12	18.3	17.8
16	No treatment	—	—	—	—	—	–	57	17.1	18.2

The summer sprays included three applications of summer oil over the period of second brood codling moth abundance in Ill. June 25 to August 15, a total of 15 applications within the five years. Item 11, a low viscosity unsaturated oil essentially kerosene emulsified with an inert emulsifier caused no injury though the test. Item 12, an 83 second unsaturated oil, did in all sprays cause some injury as a spotting of both fruit and foliage. The injury was never sufficient to cause a dropping of either fruit or foliage. Items 13, 14, 15 including 32, 83 and 200 second viscosity saturated white oils in no cases injured foliage, although the two heavier oils in a few cases caused a spotting of Grimes fruit. (Abnormal retention of the green color on ripe fruit.) Item 16 groups the untreated controls.

Table 3 summarizes the growth during the last three years of trees included in Table 2. Item 1 groups together all trees receiving dormant sprays; Item 2 all trees receiving summer sprays and Item 3 the untreated controls. With rather large numbers of trees there is no real difference in growth between the treatments and the control as measured by trunk circumference and height. The amount of fruit and bloom on this orchard has been too light to justify a study of the effects of the treatments on these factors.

TABLE 3. SUMMARY OF GROWTH ON JONATHAN, GRIMES, AND DELICIOUS APPLE TREES 12 TO 16 YEARS OLD—SPRAYED SINCE 1929 (5 YEARS) WITH OIL EMULSIONS

Item No.	Spray	Per cent concentration	Yearly No. sprays	No. trees	Average height 1934 (feet)	Percentage increase in trunk circumference, 1932 to 1934
1	Dormant sprays of oil	2 to 8	1	113	17.4	17.4
2	Summer sprays of oil	2	3	56	17.5	17.0
3	No treatment	–	0	57	17.1	18.2

SUMMARY.—Dormant oil sprays applied over 5 and 10 year periods to relatively young apple trees did not affect tree growth measureably under orchard conditions. An application of 8 per cent dormant oil has

consistently delayed bud opening on all varieties from 3–7 days. Concentrations of 2 and 3 per cent have occasionally caused a slight retardation for 2–3 days.

Summer applications of an unsaturated oil of 32 seconds viscosity did not injure either fruit or foliage. An 83 second viscosity unsaturated oil injured both fruit and foliage. The saturated oils gave little to no injury when applied in 3 sprays of two per cent concentration between June 25 and August 15. The growth of apple trees receiving three sprays of summer oil was not measureably different from the untreated controls.

SOME RECENT DEVELOPMENTS IN REGARD TO TAR DISTILLATE AND TAR-LUBRICATING OIL SPRAYS[1]

By F. Z. HARTZELL, S. W. HARMAN, and T. W. REED

The subjects discussed in this paper fall under two general heads, viz., (1) effect of dormant treatments of tar distillate and tar-lubricating oil sprays on trees subjected to extreme winter temperatures, and (2) need of standardization and correct labeling of all oil preparations intended for use on trees. These two phases of the investigation are closely related. Because of the current ambiguous terminology it seems advisable to define the terms that will be used in this presentation. By *tar oil emulsion*, *tar distillate emulsion*, or *creosote oil emulsion* is meant any preparation consisting only of tar oils with the addition of an emulsifier. The term *tar-lubricating oil emulsion* will be used for those mixtures containing any proportion of tar oil, lubricating oil and emulsifier. For brevity the term *emulsion* will be used for all oils that are miscible with water. Other terms will be defined later.

RELATION OF OIL SPRAYS TO WEAKENED TREES.—During the winter of 1933–34 New York was subjected to unprecedented cold weather. In most fruit areas minimum temperatures from — 20° to — 40°F., were experienced; i. e., from 10 to 20 degrees below the usual winter minima for the various localities. Thousands of apple trees died and many more were seriously weakened. Entire peach orchards were killed, while cherry and pear trees suffered severely. It is believed that the drought extending thru 1933 and 1934 greatly accentuated the damage in western and central New York. There were marked differences between varieties and between trees of the same variety as regards their susceptibility to injury even when subjected to the same temperatures. Two small areas on the shore of Lake Ontario did not experience such extremes; the Niagara area in northwestern Niagara county and the Sodus area in northern Wayne county. In the former place minimum temperatures of from — 12° to — 20°F., were recorded, while in the Sodus area the minimum temperatures ranged from — 16° to — 20°F. With the exception of destruction to some peach buds, slight damage occurred to fruit trees in both places.

[1]Approved by the Director of the New York State Agricultural Experiment Station for publication as Journal Paper No. 76, January 4, 1935.

In the Niagara area sweet cherries were sprayed in the spring with tar distillate 1.8 per cent, and several varieties of apple trees received 3 and 5.4 per cent of the same material. Other apple trees of the same varieties were treated with 3 and 6 per cent of lubricating oil.[2] No injury was produced by any of the treatments. In the Sodus area, the tests applied by the writers included 1.8 per cent tar distillate on sweet cherries and 3 per cent concentration on several varieties of apples. No injury occurred on the apples, but the set of sweet cherries was somewhat reduced where temperatures of — 20°F., were experienced. Similar tests were made on two varieties of apples at Lyons, in southern Wayne county, when the minimum temperature was — 31°F. Here the set of fruit was considerably curtailed. In all the tests thus far described one-half of each tree was treated and the other half left as check.

At Geneva (minimum temperature — 31°F) all experiments in one series of spring applications were on apples. One-third of each tree was treated with some mixture, another third with another mixture, and one-third of the crown was left untreated. There were 29 varieties, 1 tree each; 2 other varieties, 2 trees each; and still another variety in which 4 trees were used. The mixtures included lubricating oil, 2 and 3 per cent; tar distillate, 2 and 3 per cent; and tar-lubricating oil 2, 3, 4, 5 and 6 per cent of total oil.

In another series at Geneva, 9 entire trees of 3 varieties were sprayed in the fall with a tar-lubricating oil emulsion having a total oil content of 4 per cent and other trees of the same varieties were left as checks.

In still another series of 54 trees at Geneva, Greening trees about 18 years of age were treated in the fall and others in the spring, using a tar-lubricating oil emulsion at a total oil concentration of 1.6, 2.4, 4.0 and 6.0 per cent. Spring applications of several of these dilutions were also made to a number of weakened trees in the same orchard. Lubricating oil emulsion at 3 and 6 per cent, to which was added ½ per cent of cresylic acid, were applied in the fall and in the spring on other trees in this series. In this orchard entire trees were treated with a single mixture and others were left untreated for comparison. The results at Geneva may be summarized as follows:

At present, under western New York conditions, there appears to be no good reason for using mixtures of tar distillates and lubricating oil unless the concentration of the latter is sufficient to control San Jose scale and the proportion of creosote oil is adequate for the rosy aphid or other insects whose destruction is sought. The chief reason for not using mixtures of the two oils is that they appear to be more toxic to weak trees than either oil alone when the total oil content is the same. When applied in the spring, on trees of the same variety and vigor, lubricating oil and tar oil at the same concentrations produced about the same effects on the crop, but in fall treatments the lubricating oils were more injurious to the wood and also decreased the crop more than tar oils used at the same dilution.

[2]The applications were made by W. E. Blauvelt of the Entomological Department of Cornell University and J. J. Goodrich of the Niagara County Farm Bureau whom the writers wish to thank for doing this part of the field work.

On trees severely weakened by the winter each kind of oil used at strengths necessary for San Jose scale or rosy aphid appeared to cause considerable injury to the trees and to the set of fruit. On light to moderately weakened trees tar oil and also lubricating oil proved reasonably safe provided the concentration did not exceed 3 per cent and the spray did not contain a mixture of the two oils. Winter hardy trees were uninjured by spring applications of either or both oils provided the total oil content did not exceed 5 per cent.

Fall treatment with tar-lubricating oil emulsions containing approximately 65 per cent of creosote oil and 15 per cent of lubricating oil, on moderately vigorous and vigorous trees seems to indicate less injury to the limbs and set of fruit than did spring applications using the same dilutions, provided the total oil content did not exceed 4 per cent. At higher concentrations the fall treatment produced practically the same effects as the spring applications.

APPROXIMATE STANDARDIZATION OF OIL SPRAYS.—The term *standardization* as usually employed connotes a degree of refinement that with present knowledge is impossible with tar oil and lubricating oil sprays so its use in this discussion is limited to *approximate* standardization which, while evidently leaving much to be desired, is practical. Two phases are recognized: delimitation of the basal materials and uniformity in proportion of the constituents in the emulsions. The object of the former is to make sure that growers are purchasing mixtures whose basal materials are quite similar to those used in the experiments upon which recommendations for use of oil sprays are founded. The basal material will approximate practically all those which were proven to have merit if the tar distillate meets the following specifications:

1. It shall be derived from tar secured from bituminous coal, the latter having been heated to high temperatures in gas retorts or by-product coke ovens in the making of illuminating gas.
2. Based on freedom from water the tar oil shall distil within the following limits:
   At temperatures up to 410° F (210° C) not more than 1 per cent.
   At temperatures up to 455° F (235° C) not more than 10 per cent.
   At temperatures up to 671° F (355° C) not less than 65 per cent.
3. It shall contain not more than 3 per cent water.
4. It shall contain not more than 10 per cent tar acids and less than 5 per cent is to be preferred.
5. It shall remain free from crystals on standing 3 hours at 41° F (5° C) with occasional stirring.
6. Tests 2, 3 and 4 shall be in accordance with the standard methods of the Society of Testing Materials.

The distillate meeting these tests is known to the trade as *refined straight-run coal tar creosote oil* and in this article is abbreviated to the term *creosote oil* except in the paragraph discussing the several distillates which are commonly known as creosote oil.

Since creosote oil consists of chemical compounds, some of which are unknown, and since the proportion of these compounds vary more or less in different batches from the same plant, depending on the source of the coal and manipulation, in material from different plants, or in the type of retort used, and especially because the specific action of many of these compounds on insects and plants are not known, there is no

reason for making the specifications more definite than those given above.

The term *tar* when unqualified refers to a black, viscous mass secured as a distillation product from many sources, so for greater definiteness an adjective is prefixed. Thus there is wood tar, peat tar, lignite tar, shale tar, oil gas tar, water gas tar, Pintsch gas tar, blast furnace tar, coal tar, each of which differs from the others. Coal tar is further defined according to the kind of plant used for the distillation, the three principal being horizontal retort tar, vertical retort tar, and by-product coke oven tar. Oils secured from each of these three kinds of coal tar have been found satisfactory for use on trees. Oils can be distilled from any of the other tars mentioned but no data are known to the writers as to their effects on insects and trees. Water gas tar oil seems to be the only one that has been suggested as a substitute for creosote oil. It appears that, because of price consideration, some manufacturers had contemplated such a change just recently. On the advice of the senior author, the change was not made. In order that manufacturers who are using creosote oil may not suffer from this competition and also to protect growers, it is important that the label on each container states the source of the tar oil. It is not meant to infer that oil from other tars will not find use for tree spraying, but rather that lack of knowledge makes their use inadvisable at present.

Perhaps no term used by tar distillers is so ambiguous as creosote oil. This is shown by the tabular arrangement of coal tar oil fractions (Table 1). Thus it will be noted that four distinct fractions are called creosote oil, by different distillers. Listing the distillation limits on the label would not only obviate the confusion that might result from the term "creosote oil" but give evidence of the extent to which the lower boiling fractions have been eliminated. The term *refined straight run coal tar creosote oil* is the most definite. In some commercial emulsions all the fractions below 235° C., and in others all below 270° C., have been eliminated. Field tests did not show striking differences between brands having oils with the minimum boiling point at 200 and those with all fractions distilling above 270°C. For this reason it is not possible at present to state definitely which minimum is to be preferred.

TABLE 1. FRACTIONS AND TERMS USED BY TAR DISTILLERS AND THE TRADE

Distillation range	Terms used by European and some American distillers	Terms used by some American tar distillers	
To 110° C.	Light oil	Light oil or crude naphtha	
110° to 210° C.	Light oil or Second light oil		
210 to 240° C.	Middle oil or Carbolic oil	Creosote oil	Creosote oil, Dead oil, or Straight-run creosote oil.
240° to 270° C.	Heavy oil or Creosote oil		
270° C to pitch (360° to 400° C)	Anthracene oil	Creosote oil	

The object in having the creosote oil crystal-free above 5°C., is to avoid crystals in the spray mixture, otherwise clogging of the nozzles might occur, especially when the water is below 40°F.

The lubricating oil included in tar-lubricating oil emulsions and in ordinary lubricating oil emulsions should also meet a certain approximate standard. The type that seems to best meet the needs for dormant applications in New York, considering safeness to different kinds of fruit trees and toxicity to insects has the following approximate specifications:

Viscosity at 100° F (Saybolt)	99 to 120 seconds
Specific gravity	0.89 to 0.92
Flash point	350° F
Fire point	450° F
Unsulfonated residue	60 to 70 per cent
Volatility after 4 hours (220° to 230° F)	0.25 per cent

Having defined the approximate standardization of the basal materials, some consideration should be given to uniformity in the proportion of the constituents of commercial emulsions. If the first number represents the percentage of creosote oil and the second number the percentage of lubricating oil in the stock emulsions, the following mixtures have appeared on the American market: 90–0, 85–0, 83–0, 65–15, 60–23, 50–33, 40–40, 37–46, 0–66, and 0–83. The first three mixtures represent tar distillate or creosote oil emulsions; the next five, tar-lubricating oil emulsions; and the last two lubricating oil emulsions. Since, with the exception of lubricating oil emulsions, usually there were no statements on the labels indicating whether any lubricating oil was present, and since the brand names gave no more information than that the mixtures contained some tar oil, growers and workers had no way of making tank mixtures containing a definite amount of either kind of oil until chemical analyses of the brands had been made. Even if the percentage of each oil had appeared on the label, the wide variety in proportion of the two kinds of oils in the different brands made difficult the matter of dilution. This has been further complicated by the necessity of using the minimum oil content that will control particular insects on winter injured trees.

The problem would be greatly simplified if each manufacturer would make three preparations that could be mixed in any proportion without "breaking" of the emulsions: (1) a creosote oil emulsion that contains no lubricating oil; (2) a lubricating oil emulsion that contains no creosote oil; and (3) a tar-lubricating oil emulsion having the creosote oil and the lubricating oil in the ratio of 2.4 to 3 for those regions where both San Jose scale and the rosy aphid are present. If the creosote oil content were stated on the label, the first emulsion could be used alone at dilutions for any particular insect or combination of insects where the lubricating oil is not desired in the mixture. Likewise, the second emulsion could be used where tar oil is not desired. If definite proportions of the tar oils were desired in the mixture this could be effected to any degree of refinement by mixing the required amounts of the two emulsions.

CORRECT LABELING OF CONTAINERS.—The label of each container should state (1) the source, specifications and percentage of the creosote oil if present, (2) the specifications and percentage of the lubricating oil if present, and (3) whether or not either or both of these oils are present in brands purporting to belong to either class of spray preparation. If the statements meeting the specifications given in this paper and the per-

centage of each oil present are included, growers will know they are buying materials similar to those recommended and will be able to make definite dilutions for the various insects. Furthermore, the manufacturer will know that he is furnishing emulsions whose basal materials are similar to those found effective against certain pests. He will also be protected against competition by brands containing basal materials from other sources or having less desirable specifications and against the improper use of his brands by growers thru lack of knowledge as regards the proportion of each oil present.

DIESEL OIL EMULSIONS AS INSECTICIDES[1]

By WALTER CARTER

Although there is an increasing recognition of the occasional deleterious effects of petroleum oil sprays even when unsulphonatable oils are used, the sulphonation test is still considered to be the best single criterion by which the objectionable properties of an oil may be measured.[2] [3]

Highly sulphonated oils have been used successfully for the control of *Pseudococcus brevipes* (Ckl.) in Hawaii and mealy bug wilt has been practically eliminated. The present study was begun as a result of sharp increases in price of the emulsions and oil stocks in use and desirability of reducing costs.

SPECIFICATIONS OF OILS USED.—The oils used are the typical Diesel fuel oils. They are widely used in Hawaii as weed killers in addition to their use as motor fuel.

Specifications are listed in Table 1.

TABLE 1. SPECIFICATIONS OF SOME DIESEL FUEL OILS USED IN THE MANUFACTURE OF INSECTICIDAL EMULSIONS

Specifications	Fuel Oil 27 plus[1]	Fuel Oil 30 plus[1]	Fuel Oil 34 plus[1]
A. P. I. gravity	29.3	30	34.4
Flash (Penaky-Martens)	186° F.	—	142° F.
Vis. at 100° F. (Saybolt-Univ.)	38	42	33
Vis. at 130° F. (Saybolt-Univ.)	36	—	32
Sulfur	0.52%	—	0.28%
Pour Point	Below 70° F.	—	Below 35° F.
B. T. U. per pound	19,350	—	19,482
Sediment and water	Trace	—	Bright
Carbon-Conradson	0.08%	—	Trace
A. S. T. M. distillation			
Initial	392° F.	225° C.	362° F.
10%	442	254	391
50%	515	287	441
80%	600	318	486
90%	656	343	514
End point	730	382	586

[1]Trade designations.

[1]Published with the approval of the Director as Technical Paper No. 82 of the Experiment Station of the Pineapple Producers Cooperative Association, University of Hawaii.

[2]Young, Paul A. and H. E. Morris. 1933. Injury to apple by petroleum-oil sprays. Jour. Agr. Res., 47(7):505–522.

[3]English, L. L. 1928. Some properties of oil emulsions influencing insecticidal efficiency. Illinois Natural History Survey Bulletin. 17(5):235–259.

EMULSIFICATION.—Colloidal clays were used as emulsification agents and of these, various grades of bentonite proved most satisfactory. In determining the suitability of any particular mix, the factors of smoothness, presence or absence of small masses of unmixed bentonite, and "break," either of water or oil, were considered. In Table 2 are listed examples of emulsions considered satisfactory according to the criteria mentioned above.

TABLE 2. EXAMPLES OF PROCEDURES RESULTING IN SMOOTH HOMOGENOUS EMULSIONS FREE FROM "BREAK"

Oil	Proportions (ccs.) Oil	Water	Amount of bentonite (gms.)	Notes
27+	100	100	10	Free flowing
27+	100	100	15	Viscous; smooth
27+fish oil	60 40	100	10	Free flowing
34+	100	100	10	Free flowing
34+	100	100	15	Viscous but free flowing
34+fish oil	60 40	100	10	Free flowing
27+	100	100	7.5	Free flowing
27+	150	150	10	Free flowing

It is evident from a long series of experiments from which the examples of Table 2 are drawn, that the amount of Diesel oil which can be emulsified with water is limited within a rather narrow range. For that reason subsequent emulsions were mixed on the basis of equal quantities of oil and water, emulsified with bentonite at the rate of 1 pound to 1 gallon of the oil. A typical formula therefore was:

10 gallons water
10 pounds bentonite
10 gallons Diesel oil (27 plus)

The order of mixing was, at first, in the order named. In later mixing this was reversed and the oil and bentonite mixed before the water was added.

RESULTS WITH BENTONITES FROM VARIOUS SOURCES.—The term "bentonite" is generic and samples from various locations reveal differences which are of considerable importance in determining emulsification qualities. Unfortunately no definite criteria are available whereby these differences can be evaluated and in view of the increasing use of bentonite in the insecticide field this would appear to be a fruitful source of inquiry.

An attempt was made to find a simple laboratory test wherewith to compare bentonites and the method described in "Bentonite," Bulletin No. 107, Silica Products Company, Kansas City, Missouri, 1930, for increasing the dispersal of a Nevada bentonite was used with slight modification. One gram of each bentonite was mixed thoroughly in a Gilchrist mixer with 100 cubic centimeters of a 0.16 per cent solution of sodium hydroxide. The mixture was then poured into graduated cylinders and the amount of dispersal noted. These data are tabulated in Table 3. Samples of emulsions were then made up using these bentonites with a 10–10–10 formula. Notes on the resulting emulsions are included also in Table 3.

TABLE 3. GEL TESTS OF A NUMBER OF BENTONITES WITH EMULSIFICATION DATA

Bentonite[1]	Dispersal[2] 4 hrs. ccs.	24 hrs. ccs.	72 hrs. ccs.	Emulsion, 10–10–10
Clay spur Wyoming	84	65	50	Stiff: smooth: no free oil
Argosite 300	26	22	21	Stiff: smooth: no free oil
Tamsite, Ill.	95	83	65	Stiff: smooth: no free oil
Argosite 200	61	44	42	Very stiff: considerable free oil
Cala 1	92	77	58	Smooth but free oil in excess
Cala 2	100	98	97	Stiff: smooth: no free oil
Cala 3	27	20	18	Uneven stiffening: very slight free oil
Cala 4	70	43	37	Spongy conglomerate with free oil in interspaces
Cala	44	37	34	Smooth but free oil in excess
San Benito[3]	97	82	62	Fluid: smooth: no free oil

[1]Designations and samples from Braun-Knecht-Heimann-Co..
[2]See page 272 for definition.
[3]Type used in field tests.

There appears to be no correlation between the results of the gel test used and the smoothness and stability of emulsions made up with a 10–10–10 formula. In the case of the emulsions noted as breaking, stability has been improved by modifying the amount of bentonite used.

Although it seems likely that the relative colloidal properties of bentonite will be of more significance in evaluating emulsification properties than will the standard analysis, such data as are available are listed in Table 4.

TABLE 4. ANALYSIS OF SOME BENTONITE SAMPLES[1]

	Cala 1	Cala 2	Cala 3	Cala
Silica (SiO_2)	52.32	31.38	44.45	69.83
Aluminum oxide (Al_2O_3)	18.74	1.18	2.70	14.61
Titanium Oxide (TiO_2)	0.10	——	——	——
Iron Oxide (Fe_2O_3)	1.20	1.36	0.57	1.71
Calcium Oxide (CaO)	0.96	24.26	15.15	0.33
Magnesium Oxide (MgO)	4.35	11.29	15.70	3.44
Potassium Oxide (K_2O)	0.41	——	0.12	1.49
Sodium Oxide (Na_2O)	4.98	3.19	1.32	3.14
Sulphuric Anhydride (SO_3)	0.33	——	——	——
Chlorine (Cl)	1.03	0.13	——	——
Phosphoric Anhydride (P_2O_5)	0.04	——	——	——
Carbon Dioxide	Trace	——	——	——
Moisture, combined water and volatile matter	15.54	27.21	19.99	3.88
Undetermined	0	0	0	1.57
	100.00	100.00	100.00	100.00

[1]Additional analyses may be found in "Bentonite", Bulletin No. 107, Silica Products Company, 700 Baltimore Avenue, Kansas City, Missouri.

VARIATION IN EMULSIONS DUE TO METHOD OF MIXING.—Laboratory mixing was done, for the most part, in a Gilchrist No. 22 mixer. The mixing device on this apparatus is a small partly corrugated disc revolving at approximately 1800 r. p. m. Even with the small amounts of material mixed in this device it was necessary to move the container up and down so as to have the spinning disc operate throughout the mass of material in order to get thorough mixing. For larger quantities, mixers of the egg beater type were used. Comparison of the emulsions produced by the two methods of mixing indicated that smoother more homogenous emulsions resulted from the high-speed spinning type of mixer. Preliminary experiments on the toxic effects of the oils on pineapple plants showed a decided difference between the two types of emulsion, those made by the egg beater type being definitely more toxic than those made with the high spinning disc. In appearance, the high speed mixed emulsions are smoother and more homogenous, suggesting that with high speed mix-

ing the bentonite particles undergo a preliminary swelling. This swelling, as will be shown later in this paper, is an important factor in rendering the oils safe for use on plants, so that when it became necessary to make larger quantities for field use, a simple high speed mixer was devised which is illustrated in Figure 32.

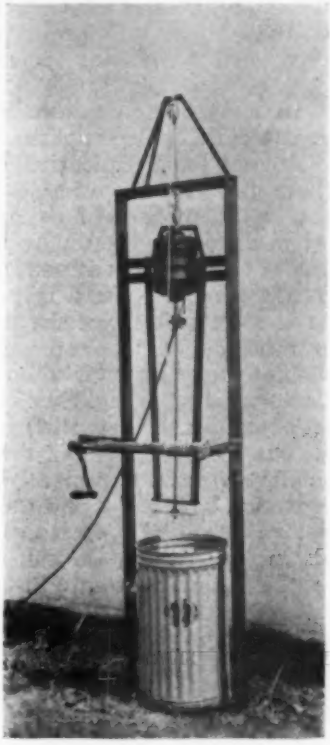

FIG. 32.—Mixing device used for bulk manufacture of Diesel oil emulsion.

METHODS FOR IMPROVING THE HOMOGENEITY AND STABILITY OF DIESEL OIL EMULSIONS.—The simplest method is to increase the proportion of bentonite. A much smoother and more homogenous emulsion was obtained when the amount of bentonite was increased 50 per cent, using 15 grams to 100 cubic centimeters each of oil and water.

Other methods have depended upon the fact that with change of isoelectric point, bentonite particles in water, hydrate and swell.

The addition of small quantities of acid to emulsions of formulae as given in Table 2 produces an extreme swelling of the bentonite with the result that the emulsion is materially stiffened. The same result can be

obtained by adding small quantities of salts as listed in Tables 6 to 8. There is definite relationship between amount of acid or of salt added and the hydration of the bentonite obtained and if sufficient is added the emulsion becomes a practically solid mass.

The addition of Blood Albumen spreader to the concentrated emulsion results in a great improvement in smoothness. This is a curious phenomenon since Blood Albumen spreader tests neutral when diluted. The suggestion herein is that the addition of a foreign colloid affects the surface phenomena involved with a resulting increased smoothness and homogeneity.

INCORPORATION OF OTHER INSECTICIDES AND FUNGICIDES IN EMULSIONS.—This has been successfully accomplished by the addition of sulphur in the form of "Kolofog" and of nicotine, by the addition of "B. L. 155." Since both these materials have bentonite bases their incorporation is easy and can be accomplished by simply substituting them for part of the bentonite in the original formulae. The "B. L. 155" however reduced the stability of the emulsion somewhat.

EFFECT OF AGE ON EMULSIONS.—There is generally an increased stiffening noted. This is accelerated by exposure to the air. When this is long continued the bentonite mass hardens and contracts with a resulting release of free oil. The stiffer the emulsion is when mixed the more rapid is the subsequent hardening and breaking. Emulsions kept covered and out of excessive heat have retained their stability for months.

DISPERSAL OF DIESEL OIL EMULSIONS.—For the purpose of this paper "dispersal" is defined as the volume occupied by the oil-charged bentonite particles after agitation has ceased and the spray fluid has come to rest: "dispersal ratio" is the ratio between this volume and the original volume of emulsion introduced into the spray water.

The dispersal of the oil-charged bentonite in the spray water is undoubtedly the most important factor in reducing the phytotoxic characteristics of the oil to negligible proportions.

DISPERSAL IN CONCENTRATED EMULSIONS.—When emulsions which have been stiffened by the addition of acid or of salts are diluted, in comparison with emulsions of the same formulae but without stiffening, an increase in dispersal ratio is noted. The technique used was to add 10 cubic centimeters of emulsion to 90 cubic centimeters of water and record the breaking of the mixture into zones, at definite intervals. Some examples are listed in Table 5.

TABLE 5. DISPERSAL RATIOS OF DIESEL OIL EMULSIONS WITH AND WITHOUT THE ADDITION OF STIFFENERS TO THE CONCENTRATED EMULSION

Stiffening agent		None	H_2SO_4 1 cc. in 200 ccs.	$ZnSO_4$ 0.5 gms. in 200 ccs.	Blood albumen	$FeSO_4$ and $(NH_4)_2SO_4$ 0.5 gms. each in 200 ccs.	$FeSO_4$ 0.5 gms. in 200 ccs.
Dispersal ratio	1 hr.	1	4.5	6	1	6	9
	24 hrs.	1	3.5	3	1	4	3.5

DISPERSAL IN TREATED SPRAY WATER.—In these experiments the technique was the same as for those with concentrated emulsions except that in lieu of water, dilute aqueous solutions of various compounds, principally acids and salts, were used. The results are given in Tables 6

to 8. It is evident from these data that the kind and concentration of material used as a diluent affects the final dispersal of the oil-charged bentonite particles. Dispersal of bentonite particles can also be accomplished by modifying the iso-electric point in the opposite direction with sodium hydroxide as shown in Table 7.

TABLE 6. DISPERSAL TESTS OF DIESEL FUEL OIL EMULSIONS IN DILUTE ACID SOLUTIONS. ALL DILUTIONS 10 CCS. OF EMULSION AND 90 CCS. DILUENT

Acid	Per cent	Time (Min.)	Notes	Dispersal ratio
Acetic	1	6	46 cc. clear zone: balance heavy flocculent particles	
		30	55 cc. clear zone	
		60	60 cc. clear zone	4
	0.5	6	13 cc. flocculent layer on surface	
		15	12 cc. flocculent layer	
		60	No change	1
Citric	0.5	6	90 cc. flocculent particles; 10 cc. clear zone	
		15	83 cc. flocculent	
		60	60 cc. flocculent	6
	0.1	6	76 cc. flocculent	
		15	47 cc. flocculent	
		60	33 cc. flocculent	3
Sulphuric	0.1	6	60 cc. curdled pellets	
		15	55 cc. curdled pellets	
		60	40 cc. curdled pellets	4
	0.01	6	42 cc. flocculent	
		15	35 cc. flocculent	
		60	28 cc. flocculent	2.8
	0.001	6	2 cc. dark brown layer	
		15	6 cc. dark brown layer	
		60	9 cc. dark brown layer	1

The results with Blood Albumen spreader which tested neutral at the dilutions used, indicate that dispersal of bentonite is accomplished to some extent by the addition of a foreign colloidal suspension. Since this material is now widely used as a simple spreader in tank-mix spraying it could, no doubt, be readily adapted to this new purpose.

The use of zinc sulphate in the process is of considerable interest in view of the use of that material in the correction of nutritional diseases of citrus. The use of iron and ammonium sulphates is particularly practical in Hawaii since both materials are readily available on all pineapple plantations. Experience with these last two materials, however, has shown that when used as part of an insecticide, the insecticide application should be the primary objective.

In Figure 33 are shown examples of dispersals obtained with zinc sulphate and Blood Albumen. It will be noted that at a dilution of 0.06 per cent Blood Albumen, the increase in dispersal is practically nil.

In all cases, dispersal ratios under field conditions have been greater than in the laboratory with the same strength diluents, due, presumably, to the effect of greater masses of emulsion and greater volumes of water on the surface phenomena involved. A series of samples taken to determine the distribution of oil in a large spraying machine having a 1200 gallon tank, illustrates this point, and the data are in Table 9.

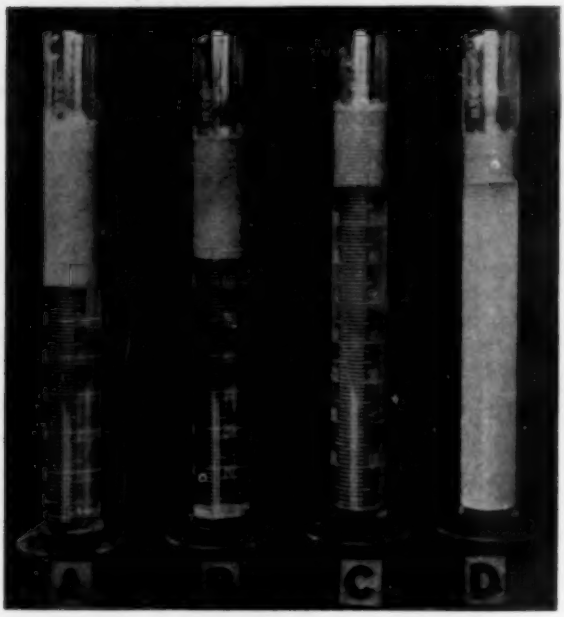

FIG. 33.—Dispersals of a Diesel oil-bentonite emulsion after 24 hours. 10 cc. emulsion in 90 cc. diluent: A. Zinc sulphate, 0.2%; B. Zinc sulphate, 0.04%; C. Blood albumen, 0.125%; D. Blood albumen, 0.06%.

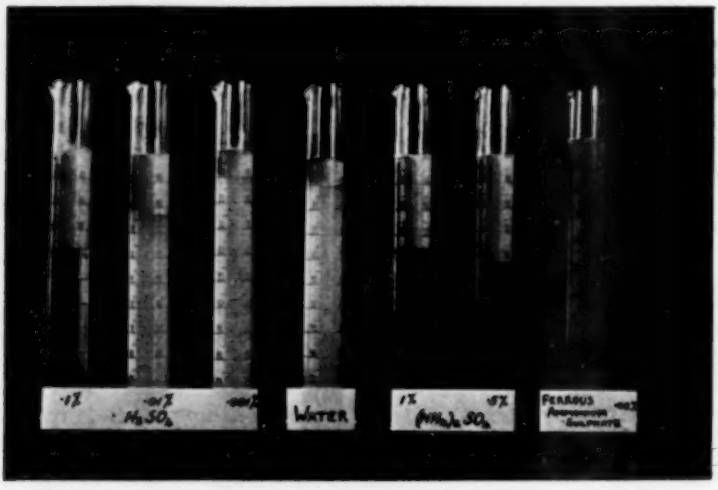

FIG. 34.—Dispersal test showing lack of correlation between pH value and dispersal. pH values reading from left to right: 0.1%—1.9; 0.01%—2.9; 0.001%—7.4; Water—7.6; 1%—6.7; 0.5%—6.8; 0.02%—5.4.

TABLE 7. DISPERSAL TESTS OF DIESEL OIL EMULSIONS IN DILUTE SALT SOLUTIONS. ALL DILUTIONS 10 CC. OF EMULSION AND 90 CC. SOLUTION

Salt	Per cent	Time (min.)	Notes	Dispersal ratio
Iron sulphate	.1	6	Homogenous flocculence	
		15	Homogenous flocculence	
		60	92 cc. flocculence: 8 cc. clear zone	9
	.02	6	6 cc. dark brown dense layer at top; 60 cc. flocculent particles	
		15	No change	
		60	No change	6
	.01	6	6 cc. dark brown dense layer	
		15	9 cc. dark brown dense layer	
		60	10 cc. dark brown dense layer	1
Ammonium sulphate	1	6	Homogenous flocculence	
		30	63 cc. flocculence	
		60	52 cc. flocculence	5
	.1	6	1 cc. granular layer at top; 5 cc. flocculence	
		60	10 cc. granular layer at top	1
Ferrous ammonium sulphate	.01	6	4 cc. granular top layer	
		15	8 cc. granular top layer	
		60	10 cc. granular top layer	1
	.02	6	90 cc. flocculent top	
		15	55 cc. coarse flocculent top; 25 cc. clear; 20 cc. fine flocculent bottom	
		60	40 cc. coarse flocculent top; 30 cc. medium clear zone; 30 cc. fine flocculent bottom	7
Zinc sulphate	.2	6	Homogenous flocculence	
		15	Homogenous flocculence	
		60	86 cc. flocculence	8
	.04	6	Homogenous flocculence	
		15	90 cc. flocculence	
		60	56 cc. flocculence	5.6
Blood albumen spreader	.125	6	73 cc. flocculence	
		15	40 cc. flocculence	
		60	30 cc. flocculence	3
	.06	6	45 cc. flocculence	
		15	23 cc. flocculence	
		60	15 cc. flocculence	1.5
Sodium hydroxide	1	6	Homogenous flocculence	
		15	96 cc. homogenous flocculence	
		60	75 cc. homogenous flocculence	7.5
	.1	6	Homogenous flocculence	
		15	Homogenous flocculence	
		60	Homogenous flocculence	6
	.05	6	2 cc. light brown surface layer	
		15	Further concentration at surface without clear demarkation	
		60	Further concentration at surface without clear demarkation	1

FACTORS AFFECTING DISPERSAL.—Although acid- and hydroxyl-ion dispersal of bentonite is a recognized phenomenon, the data of this paper indicate that when salt solutions are used, dispersal is not a function of the pH. This is seen in Figure 34 which shows the relative dispersal obtained with 3 concentrations of sulphuric acid, 2 of ammonium sulphate and 1 of ferrous ammonium sulphate, all compared with the dispersal obtained with untreated tap water.

TABLE 8. DISPERSAL TEST WITH DIESEL OIL EMULSIONS DILUTED WITH WEAK AQUEOUS SOLUTIONS OF $FeSO_4$ AND $(NH_4)_2SO_4$ IN COMBINATION

Quantities used						
$FeSO_4$ (gms.)	$(NH_4)_2SO_4$ (gms.)	Water (ccs.)	Emulsion (ccs.)	Time	Notes	Dispersal ratio
.1	.5	90	10	6 min.	Homogenous floc.	
				60 min.	Homogenous floc.	10
				24 hrs.	49 cc. floc., 51 cc. clear zone	5
.05	.5	90	10	6 min.	Homogenous floc.	
				60 min.	Homogenous floc.	10
				24 hrs.	48 cc. floc., 52 cc. clear zone	5
.1	.1	90	10	6 min.	Homogenous floc.	
				60 min.	Homogenous floc.	10
				24 hrs.	93 cc. floc., 7 cc. clear zone	9
.05	.05	90	10	6 min.	Homogenous floc.	
				60 min.	Homogenous floc.	10
				24 hrs.	67 cc. floc., 23 cc. clear zone	7
.5	.5	990	10		Diluted emulsion poured into 1 litre cylinder	
				6 min.	2.25 inch surface zone of large floc. particles	
				24 hrs.	Total volume 12 inches	
					Surface layer 1⅛ inch	
					Bottom layer ¼ inch	10[1]
.25	.25	990	10	6 min.	2.25 inch surface zone of flocculent particles	
				24 hrs.	Total volume 11¾ inches	
					Surface layer 1 inch	
					Bottom layer ⅜ inch	10[1]

[1]Approximate figures.

TABLE 9. DISPERSAL RATIOS OF SPRAY FLUID TAKEN AT INTERVALS IN THE EMPTYING OF A 1200 GALLON TANK FILLED WITH A 1 PER CENT DILUTION OF EMULSION IN A WEAK SOLUTION OF IRON AND AMMONIUM SULPHATES

Sample No.	Height of column (cm.)	Width of bentonite layer (cm.)	Dispersal ratio
1	10	1.3	13
2	7.5	1.5	20
3	8.5	1.5	17
4	8.5	1.5	17
5	8	2	25
6	8.5	1.7	20
7	6.3	1.3	20
8	6.8	1.3	19
9	7.5	1.3	17

Since each cylinder contains 10 cubic centimeters of emulsion it will be seen that untreated tap water and a concentration of 0.001 per cent of sulphuric acid each resulted in a dispersal ratio of 1. Both ammonium salts resulted in dispersals equal to or superior to the two higher concentrations of sulphuric acid. The opacity of the water column in the two more dilute sulphuric acid solutions and in water is due to suspensions of free bentonite particles and is typical of poorly dispersed emulsions.

It is clear from such data that dispersal of bentonite in dilute salt solutions is affected by some quality of the diluted salt rather than by its hydrogen- or hydroxyl-ion content.

The results with Blood Albumen show that dispersal may also be accomplished by the addition of a foreign colloid.

INJURY TO PLANTS.—This question has been considered of primary importance. Apart from the fact that the oils used are phytocidal unless properly handled, the pineapple plant, by reason of its structure, is peculiarly susceptible to injury. Figure 35 shows a pineapple plant from which leaves have been cut to reveal the deep well-like center. When

spray is applied to such a plant this well is filled with spray and, if the plant is normal and vigorous in its growth, remains in the center of the plant for long periods—up to many days. The result is that there is an accumulation of oil on the surface of this enclosed water, which while not at the growing point of the plant, is likely to produce a burned spot,

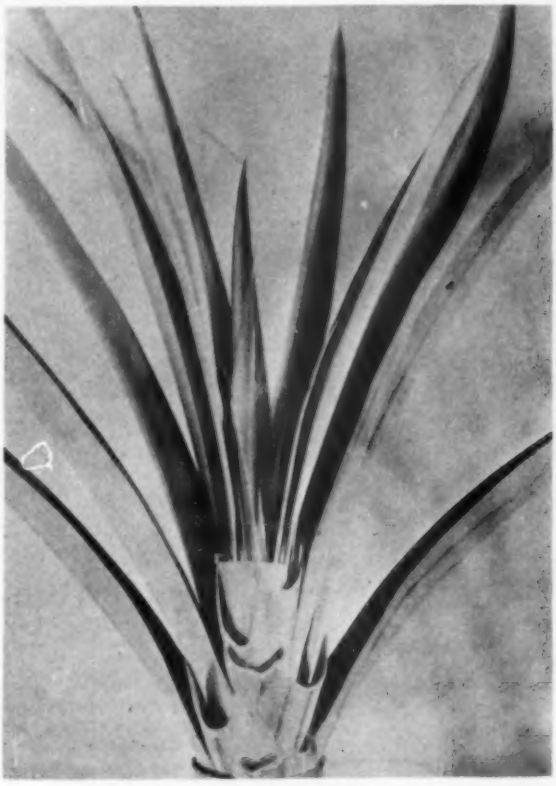

FIG. 35.—Pineapple plant with leaves cut away to show well-like center.

either yellow or necrotic, at the point of contact of oil layer and leaf. Even when the Diesel oil is adsorbed on bentonite which is then adequately dispersed the danger of oil absorption by the plant is still present because of the heavy concentration of oil on a limited leaf area.

Figure 36 is of leaves removed from the center of a pineapple plant and shows the zone left by the mass of bentonite as the spray finally drains out.

When young inflorescences are sprayed there is the additional danger of the spray pressure blowing out bracts and thus leaving open wounds into which oil can penetrate.

Field plots, after being sprayed regularly with a 10–10–10 emulsion at 1–100, at monthly intervals for 7 months without injury, did, after the eighth spray show numbers of plants with a ring of yellow or necrotic spots. This condition was general following the September and October sprays. Figure 37 shows the tips of leaves from an injured plant which was chosen as typical of the worst cases to be found. Since spraying, the plant

FIG. 36.—Upper portions of leaves showing Bentonite residue left after spray fluid has drained from plant.

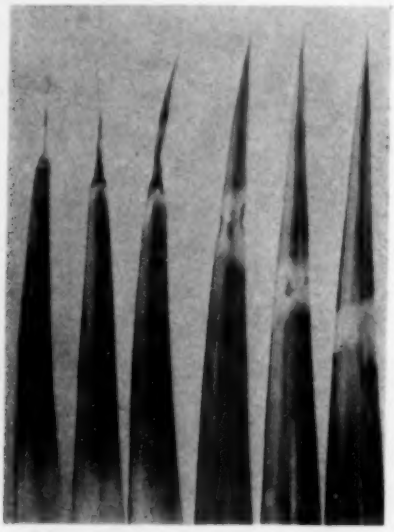

FIG. 37.—Example of severest leaf injury which occurred during most susceptible period of September–October, 1934. Tips of leaves only shown. All had grown normally after injury occurred.

had grown normally: the bases of the leaves were cut off prior to photographing the tips. There was considerable difference between fields, some showing no injury even during the most susceptible period just referred to.

Advantage was taken of this period, when the plants were making extremely rapid growth, to test the 10–10–10 formula in comparison with modifications which might prove safer. Regular field equipment was used and plots approximately ⅛ of an acre in size sprayed. Two such plots were used for each treatment and approximately 1000 gallons per acre applied. This gallonage is heavier than is normally used. Results are summarized in Table 10. In taking these data all indications of yellowing, however slight, were included.

TABLE 10. EMULSIONS USED IN FIELD TESTS ON SPRAY INJURY ARRANGED ACCORDING TO INCREASING AMOUNTS OF LEAF INJURY OBTAINED. ALL EMULSIONS USED AT 1 PER CENT STRENGTH. EACH TEST WAS CONDUCTED IN A DIFFERENT LOCATION

	Test 1				Test 2			
No.	Proportions O-B-W	Order of mixing	Diluent	Amt. in 250 gallons water	Proportions O-B-W	Order of mixing	Diluent	Amt. in 250 gallons water
1	10–15–10	OBW	$FeSO_4$	1 lb.	10–15–10 8 oz. $ZnSO_4$[1]	OBW	Blood albumen	½ lb.
2	10–15–10	WBO	$FeSO_4$	1 lb.	10–15–10 8 oz. $ZnSO_4$[1]	OBW	Mixed $FeSO_4$ and $(NH_4)_2SO_4$	¼ lb. each
3	10–10–10[2]	WBO	Mixed $FeSO_4$ and $(NH_4)_2SO_4$	¼ lb. each	10–15–10	OBW	Mixed $FeSO_4$ and $(NH_4)_2SO_4$	1 lb. each
4	10–10–10	WBO	$FeSO_4$	1 lb.	10–15–10 8 oz. $ZnSO_4$[1]	OBW	Mixed $FeSO_4$ and $(NH_4)_2SO_4$	1 lb. each
5	10–10–10	OBW	$FeSO_4$	1 lb.	10–15–10	OBW	Mixed $FeSO_4$ and $(NH_4)_2SO_4$	¼ lb. each
6	10–10–10	OBW	Mixed $FeSO_4$ and $(NH_4)_2SO_4$	¼ lb. each	10–10–10[2]	WBO	Mixed $FeSO_4$ and $(NH_4)_2SO_4$	¼ lb. each
7	10–10–10	OBW	$ZnSO_4$	1 lb.	10–15–10 8 oz. $ZnSO_4$[1]	OBW	Water	
8	6–4–6	OBW	$FeSO_4$	1 lb.	10–10–10 8 oz. $FeSO_4$[1]	OBW	Mixed $FeSO_4$ $(NH_4)_2SO_4$	¼ lb. each
9	10–10–10	WBO	$ZnSO_4$	1 lb.	10–15–10 1.5 oz. Blood Albumen[1]	OBW	Mixed $FeSO_4$ and $(NH_4)_2SO_4$	¼ lb. each
10					10–10–10[2]	WBO	Mixed $FeSO_4$ and $(NH_4)_2SO_4$	¼ lb. each
11								
12								
13								

	Test 3				Test 4			
No.	Proportions O-B-W	Order of mixing	Diluent	Amt. in 250 gallons water	Proportions O-B-W	Order of mixing	Diluent	Amt. in 250 gallons water
1	10–15–10	OBW	Blood Albumen	½ lb.	10–15–10 8 oz. $ZnSO_4$[1]	OBW	Blood Albumen	¼ lb.
2	10–15–10 8 oz. $ZnSO_4$[1]	OBW	Blood Albumen	¼ lb.	10–15–10	OBW	Mixed $FeSO_4$ and $(NH_4)_2SO_4$	1 lb. each
3	10–15–10 8 oz. $ZnSO_4$[1]	OBW	Blood Albumen	½ lb.	10–15–10	OBW	Blood Albumen	¼ lb.
4	10–10–10 8 oz. $ZnSO_4$[1]	OBW	Blood Albumen	¼ lb.	10–10–10[2]	WBO	Mixed $FeSO_4$ and $(NH_4)_2SO_4$	¼ lb. each
5	10–10–10 8 oz. $ZnSO_4$[1]	OBW	Blood Albumen	½ lb.	10–10–10 2.5 lbs. "B.L. 155"[1]	OBW	Water	
6	10–15–10	OBW	Mixed $FeSO_4$ and $(NH_4)_2SO_4$	1 lb. each	10–15–10 8 oz. $ZnSO_4$[1]	OBW	Mixed $FeSO_4$ and $(NH_4)_2SO_4$	1 lb. each
7	10–15–10 8 oz. Blood Albumen[1]	OBW	Mixed $FeSO_4$ and $(NH_4)_2SO_4$	1 lb. each	10–15–10 8 oz. $ZnSO_4$[1]	OBW	Blood Albumen	½ lb.
8	10–10–10 8 oz. $ZnSO_4$[1]	OBW	$ZnSO_4$	1 lb.	10–10–10 2.5 lbs. Bentonite sulphur[1]	OBW	Water	
9	10–15–10 8 oz. $ZnSO_4$[1]	OBW	Blood Albumen	½ lb.	10–10–10	OBW	Mixed $FeSO_4$ and $(NH_4)_2SO_4$	¼ lb. each
10					10–10–10 2.5 lbs. "B.L. 155"[1]	OBW	Blood Albumen	½ lb.
11					10–10–10 2.5 lbs. Blood Albumen[1]	OBW	Water	
12					10–15–10	OBW	Blood Albumen	½ lb.
13					10–10–10 2.5 lbs. Bentonite sulphur[1]	OBW	Blood Albumen	½ lb.

[1]Included in concentrated emulsion.
[2]Original formula.

It is clear from these tables that increasing the amount of bentonite and increasing the dispersal both in the concentrated emulsion and in the spray water reduces the danger of leaf injury at the point of concentration in the well of the plant. Tests with Blood Albumen indicate great variation between various combinations but this material seems to offer some promise when used with a well dispersed concentrated

emulsion. In practice the 10–15–10 formula with iron-ammonia is proving practical as far as pineapples are concerned.

Many additional data on spray injury have been obtained from plots which have been sprayed regularly for periods of from 7 to 10 months. One such plot has been sprayed monthly since February 1934 with concentrations of 1, 2 and 4 per cent of a 10–10–10 emulsion in two series, using iron sulphate as the diluent in one case and ammonium sulphate in the other. Injury as indicated by leaf spotting is directly proportional to the concentration used but even with the 4 per cent emulsions has not occurred consistently and has always occurred at the zone of concentration. No case has ever been noted, even with the 4 per cent concentration used, where leaf injury has occurred in the absence of retained spray fluid. It is obvious then that plants whose structure does not provide for this accumulation will not be liable to its effects and the limited experience available with trees and shrubs bears out this opinion. Mature citrus trees, lime seedlings, hibiscus and Ixora have all been sprayed with concentrations up to 4 per cent with no injury resulting to the plants.

Extensive tests have also been made on the effect of these sprays on inflorescences in all stages. In Table 11 the results are given of such a test in which sprays were applied during May, June and July of 1934. The data were taken at harvest time when the fruits were ripe. It is clear from these results which have been confirmed by later plantation tests that inflorescence sprays can be made as safely with Diesel oil emulsions as with the highly refined spray oils.

TABLE 11. SURVEY OF SPRAY INJURY ON YOUNG FIRST RATOON FRUITS AFTER THREE SPRAYS OF 1 PER CENT DIESEL OIL 10–10–10 EMULSION HAD BEEN APPLIED MAY, JUNE, AND JULY 1934. CHECK PLOTS SPRAYED WITH 1 PER CENT EMULSIFINE

Survey of previously marked fruits in sprayed plots

Treatment	Plot No.	Stage of fruit development at time of first spray	No. normal	Condition of fruit: Crowns burnt-off	Condition of fruit: Crowns dwarfed
Emulsifine	1	Flowering: Basal portion	51	—	—
		Flowering: Middle portion	67	1[1]	
		Flowering: Upper portion	67	—	1[1]
Diesel oil 10–10–10	1	Flowering: Basal portion	39	—	—
		Flowering: Middle portion	59	—	—
		Flowering: Upper portion	110	—	—
Emulsifine	2	Flowering: Basal portion	19	—	—
		Flowering: Middle portion	58	—	—
		Flowering: Upper portion	82	—	—
Diesel oil 10–10–10	2	Flowering: Basal portion	42	—	—
		Flowering: Middle portion	63	—	—
		Flowering: Upper portion	111	—	—

Survey of all the fruits in both plots

Treatment	Total No. of fruits examined	Crown burnt-off[2] No.	Crown burnt-off[2] %	Crown dwarfed[2] No.	Crown dwarfed[2] %
Emulsifine	3159	14	0.44	7	0.22
Diesel oil 10–10–10	3499	9	0.26	6	0.17

[1]Dissection of fruits showed no injury.
[2]In no case was the fruit affected.

Regular field use of these emulsions has been made by pineapple companies and over 2000 acres sprayed prior to December 1, 1934. Where leaf spotting has occurred, subsequent developments have shown it to be strictly local and of no consequence in the normal development of the plant.

Relation of Type of Bentonite Used to Leaf Injury.—In the preliminary discussion, attention was called to the various bentonites with respect to emulsification and dispersal. The six emulsions which proved stable were subjected to a field test to determine if any differences in leaf injury obtained. Plots of one-quarter acre were sprayed at the rate of approximately 800 gallons per acre with 1–100 concentrations of the six emulsions made up according to 10–10–10 formulae. The diluent used was the iron and ammonium sulphate mixture at the rate of 1 pound of each salt to 500 gallons of water.

The results of this test are given in Table 12 which gives the relative gel tests, the dispersal ratios as determined by the standard laboratory test and from samples taken from the field spray test, and the relative amount of leaf injury following the spray.

Table 12. Relation of Bentonite Type to Leaf Injury

Bentonite	24 hr. gel test	Dispersal ratios: Laboratory 1 hr.	Laboratory 24 hrs.	Field 24 hrs.	Relative injury[1]
Clay spur	65	10.0	5.0	10	12
Argosite 300	22	9.5	4.6	10	18
Cala 2	98	9.7	5.6	12	10
Cala 3	20	3.0	2.8	7	14
San Benito	82	10.0	10.0	14	25
Tamsite, Ill.	83	10.0	6.0	12	14
San Benito 10–15–10 Plantation practice	—	—	—	—	12

[1]Leaf injury in the plot showing the least injury was arbitrarily assigned the number 10 and other plots compared on that basis.

It is evident that the relative gel tests and dispersal ratios of various bentonites do not correlate with leaf injury. It is not improbable, however, that refinement of comparative tests will provide adequate criteria. The data given are concerned only with volume occupied by the dispersed bentonite; the type of dispersal varies a great deal, some showing as non-particulate masses, others as suspensions of flocculent particles of varying size. The test was useful, however, in that it showed the superiority of Cala 2 over the San Benito even when the latter was used in a 10–15–10 formulae as indicated by the discussion and data of Table 10. Incidentally this last test confirms that of Table 10 since it is shown in Table 12 that the 50 per cent increase of San Benito bentonite reduced leaf injury 50 per cent. No tests have been made to determine whether the results with the San Benito bentonite as shown in Table 10 could be repeated with other bentonite types.

Insecticidal Efficiency.—Field experiments on mealy bug control are difficult to standardize. If border plantings[4] are used the natural variation in incidence and intensity of infestation greatly affects results. New infestation may occur in the interim between surveys made before and after spraying. Results of such a test are given in Table 13.

If small isolated infested areas within fields are used it is rarely possible to find areas of equal infestation with respect to numbers of plants infested and relative size of mealy bug populations and both of these

[4]Carter, Walter. 1932. Border plantings as guard rows in pineapple mealy bug control. Jour. Econ. Ent., 25(5):1027–1030.

factors are important. Table 14 gives the results from such an area, however, which satisfied all the experimental requirements.

TABLE 13. TESTS OF INSECTICIDAL EFFICIENCY OF A 10–10–10 DIESEL OIL EMULSION APPLIED TO HEAVILY INFESTED PINEAPPLE PLANTS (1ST RATOON SUCKERS), MARCH 29, 1934. SAMPLE TAKEN APRIL 2, 1934

	Concentration: 1–100			Concentration: 0.75–100	
	Mealy bugs			Mealy bugs	
Plant	Dead	Alive	Plant	Dead	Alive
1	30	—	1	53	—
2	1	—	2	7	—
3	27	—	3	—	—
4	10	—	4	18	—
5	4	—	5	1	—
6	12	—	6	9	—
7	—	—	7	1	—
8	—	—	8	25	—
9	7	52	9	15	—
10	1	—	10	5	—
11	—	—	11	—	—
12	1	—	12	3	—
13	12	11	13	—	—
14	4	—	14	15	2
15	—	—	15	1	1
16	—	—	16	8	2
17	—	—	17	9	—
18	—	—	18	2	—
19	1	—	19	24	—
20	—	—	20	6	—
21	1	—	21	—	—
			22	9	2

TABLE 14. RESULTS OF TESTS OF INSECTICIDAL EFFICIENCY OF DIESEL OIL EMULSIONS COMPARED WITH TWO COMMERCIAL SPRAY OILS. SPRAYED OCTOBER 11, 1934; EXAMINED OCTOBER 16, 17 AND 18, 1934

		Non-fruiting stage							
		Heavy infestations				Light infestations			
Treatment	Replication	Total no. of plants	No. of plants infested after spraying	No. of plants uninfested after spraying	Per cent control	Total no. of plants	No. of plants infested after spraying	No. of plants uninfested after spraying	Per cent control
Check—not sprayed	1	542	538	4	0.7	87	79	8	9.2
	2	516	516	0	0.0	73	64	9	12.3
1–100 10–10–10 Diesel oil	1	644	31	613	95.2	106	2	104	98.1
$FeSO_4$ and $(NH_4)_2SO_4$	2	981	21	960	97.9	44	0	44	100.0
¼ lb. each—250 gals.									
1–100 Commercial dormant spray	1	715	32	683	95.5	176	1	175	99.4
oil emulsion—66%	2	1097	122	975	88.9	108	0	108	100.0
¼–100 10–3–3–10 Diesel oil with Blood Albumen	1	943	49	894	94.8	118	1	117	99.2
in concentrated emulsion	2	972	80	892	91.8	103	1	102	99.0
Diluted with water									
1–100 10–10–10 Diesel oil	1	944	90	854	90.5	188	1	187	99.5
$ZnSO_4$, 1 lb.—300 gals	2	991	83	908	91.6	71	0	71	100.0
1–100 Commercial	1	1007	47	960	95.3	123	0	123	100.0
90+U. R.—66% emulsion	2	1102	124	978	88.7	53	0	53	100.0

Dissection of plants marked as heavily infested prior to spraying gives numerical results of some value but not the true ratio between mealy bugs killed and those left alive after spraying since the high pressures

used wash off a large percentage of the initial infestation. Table 15 lists data from such an experiment.

TABLE 15. GUARD ROW PLOTS. COMPARISON OF INFESTATIONS BEFORE AND AFTER ONE SPRAYING WITH EMULSIFINE AND DIESEL OIL EMULSIONS

	Emulsifine—0.8%						Diesel oil—1%					
	Before spraying			After spraying[1]			Before spraying			After spraying[1]		
Block No.	No. of infested plants	No. of mealy bugs	Av. No. of mealy bugs on infested plant	No. of infested plants	No. of mealy bugs	Av. No. of mealy bugs on infested plant	No. of infested plants	No. of mealy bugs	Av. No. of mealy bugs on infested plant	No. of infested plants	No. of mealy bugs	Av. No. of mealy bugs on infested plant
1	12	18	1.5	5	20	4.0	13	16	1.23	1	1	1.0
2	58	502	8.66	7	11	1.57	64	960	15.0	12	42	3.5
3	119	1014	8.52	24	35	1.45	154	1960	12.72	21	58	2.76
4	204	1467	7.19	30	54	1.8	230	1948	8.46	37	62	1.67

[1]Includes all new infestations occurring between first and second counts of mealy bug infestation.

A fourth method is to maintain small experimental plantings close to sources of natural infestation. Artificial infestation of such plantings using large numbers of mealy bugs is not practical since such a procedure results in the collapse of the plants with mealy bug wilt.[5] If such plantings are initially infested with small numbers of mealy bugs, however, large colonies will develop without much mealy bug wilt ensuing.[5] Such a plot was used for the comparative test shown in Table 16.

TABLE 16. COMPARISONS OF INSECTICIDAL EFFICIENCY OF EMULSIONS SPRAYED ON TO UNIFORMLY INFESTED PLANTS

Emulsion	Per cent	Diluent	Mealy bug infestations			
			Before[1] spraying	After spraying	Per cent plants cleaned	Average population on plants still infested after spraying
10–10–10.....	1	$FeSO_4$ and $(NH_4)_2SO_4$ ½ lb. each to 250 gals. water	335	34	90	4.32
10–4–3–10[2].....	1	Water	345	51	85	1.86
10–4–3–10[2].....	0.5	Water	345	84	76	2.94
10–15–10 $ZnSO_4$[3]	1	Blood Albumen 3.2 oz. per 100 gals. water	347	35	90	2.91
10–15–10 $ZnSO_4$[3]	0.5	Blood Albumen 3.2 oz. per 100 gals. water	351	82	77	5.21
10–15–10.....	1	$FeSO_4$ and $(NH_4)_2SO_4$ ½ lb. each to 250 gals. water	395	40	90	1.6

[1]The average population of mealy bugs per plant prior to spraying was well over 100.
[2]Blood Albumen 3 lbs.; bentonite 4 lbs.
[3]At the rate of 8 ozs. to 20 gals. of concentrated emulsion.

Tables 13 to 16 indicate clearly that Diesel oil emulsions are effective in mealy bug control at concentrations which involve a much lower actual oil content than the regularly used commercial spray oil emulsions. This means that not only is a large saving made on account of the lower unit price of the Diesel oil but the cost of materials is still further reduced on account of the lower percentage of oil in the finished emulsion.

TESTS WITH OTHER INSECTS AND PLANTS.—Opportunities for extensive experiments have been lacking but heavy infestations of green scale (*Coccus viridis* Gn.) have been completely controlled on lime seedlings by three 2 per cent sprays of a 10–10–10 formula without injury

[5]Carter, Walter. 1933. The pineapple mealy bug, *Pseudococcus brevipes* (Ckl.) and wilt of pineapples. Phytopath., 23(3):207–242.

of any kind to the plants. Similar results have been obtained with the same insect on a large-leaved ornamental, *Ixora macrothyrsa* P. & B. with one spraying of 3 per cent, with no injury to the plant ensuing. Parlatoria scale (*Parlatoria zizyphus* Lucas) was completely controlled by a 3 per cent spray applied twice with an interval of one week between sprays. Heavy incrustations of mixed scale species on mature citrus trees were satisfactorily controlled with a single 4 per cent spray of a 10–15–10 formula.

SUMMARY.—It has been shown that highly sulphonated oils are not necessary to the safe spraying of succulent plants. Diesel fuel oils, when adequately emulsified and dispersed in the spray water have been successfully used for the control of *Pseudococcus brevipes* (Ckl.) on pineapples and for several species of scale on citrus and ornamental shrubs. Colloidal clays, principally bentonite, have been used and emulsions of 10–10–10 and 10–15–10 formulae have proved stable. Bentonites from various sources differ materially in their reaction to emulsification with Diesel oil. No correlation has been found between a crude gel test and emulsifying properties.

The method of agitation used in emulsification has some bearing on the smoothness and homogeneity of the resulting emulsion.

Homogeneity and stability of concentrated emulsions can be improved by increasing the amount of bentonite, by the addition of certain salts and by Blood Albumen.

Type of bentonite, methods of emulsification and especially the dispersal of the oil-charged bentonite particles are factors affecting the safe use of the oil as an insecticide.

Dispersal phenomena are not apparently dependent on pH since there is no correlation between the pH of salt solutions used in the spray water and dispersal. In addition it has been shown that Blood Albumen, a neutral compound with colloidal characteristics, can be used to achieve dispersal.

Leaf injury has been studied extensively. The anatomy of the pineapple plant insures the accumulation of a ring of concentrated emulsion on the leaf surface and when leaf spotting occurs it is at that point. Increasing the amount of bentonite in the emulsion and the concentration of salts in the spray water has practically eliminated this leaf spotting on pineapples. Other plants, such as citrus and ornamental shrubs, have been sprayed with much higher concentrations than can be used safely on pineapples and no difficulty has been encountered.

Pseudococcus brevipes (Ckl.) on pineapple has been controlled with 1–100 sprays. A number of species of scale insect on citrus and ornamentals, have been controlled with concentrations of from 1–100 to 4–100.

RELATIONS BETWEEN CHEMICAL COMPOSITION AND INSECTICIDAL EFFECTIVENESS OF ROTENONE-BEARING PLANTS

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Recent work by the authors (*6*) and others on the toxicity to insects of derris root, cubé root, and other rotenone-bearing plants has strengthened the opinion that these materials are much more effective than can be accounted for by their rotenone content alone. On the other hand, it appears that not all the material extracted by organic solvents from these plants can be considered to be as toxic as rotenone. The work described in this paper was undertaken with the purpose of obtaining a better chemical means of evaluating the insecticidal effectiveness of these materials. Although the results reported must be considered as only of a preliminary nature, nevertheless several interesting possibilities have presented themselves for further study.

About two years ago a set of eight samples of plant materials was selected for tests of their toxicity in relation to rotenone and for a study of the effect of storage. These consisted of 4 samples of derris root (one of which was known to be *Deguelia elliptica* and another *D. malaccensis*), 3 samples of cubé root, and 1 of haiari stem. (Table 1, Set A.) Preliminary tests, made some time ago, of acetone extracts of some of these samples against mosquito larvae indicated their toxicity to be greater than that which could be attributed to the amount of rotenone they contained. More recently this set of samples was used in a study of the value of kerosene extracts of derris and cubé roots against house flies (*1*). At that time it was shown that the toxicity of the kerosene extracts bore no relation to the rotenone content of the roots and, although the methoxyl content of the root gave a better indication of toxicity, it was not entirely satisfactory, no doubt partly owing to incomplete extraction. Since the publication of that work methoxyl determinations have been made directly on the kerosene extracts, and the results have been in much better agreement with the toxicity of the extracts to house flies than when the determinations were made on the original plant materials. More detailed tests of the four derris samples showed a very good correlation between the methoxyl content of kerosene extracts of these samples, prepared at three different concentrations, and their toxicity to house flies.

At about the time that the present series of tests was undertaken, it was found that some of the samples in the set of materials under study had undergone some decomposition. Hence a second set of materials was selected to be tested in addition to the first set. This second set consisted of 2 samples of derris root, 2 of cubé root, and 1 of *Cracca virginiana* root. (Table 1, Set B.) The derris and cubé samples were finely powdered materials obtained on the open market, and probably had been recently imported and ground.

DETERMINATION OF TOXICITY.—It was decided to determine the toxicity to house flies by using extracts of the plant samples in acetone.

This solvent is known to extract the toxic constituents of these plants completely and showed no toxicity to house flies by the method used. The extracts were prepared by Soxhlet extraction of 10 to 20 gram samples for 7 to 8 hours. They were made to a definite volume, and various dilutions were used for the toxicity tests. The method of testing was similar to that already described for kerosene extracts (*1*). In the present study, however, 100 flies were used in each test, and certain other modifications, such as the mounting of six spray cylinders on a rotating table, were also introduced to shorten the procedure. Mortality counts were made at the end of 3 days. The mortality in acetone checks was no greater than that of unsprayed flies.

After a few preliminary trials, tests were made of each extract at several concentrations such that mortalities both above and below 50 per cent would be obtained. Tests on the two sets of samples were conducted separately, and with each set several concentrations of a standard solution of pure rotenone in acetone were run. In the first series of tests 4 concentrations of each sample and 3 concentrations of rotenone were used, 12 tests being made at each of the concentrations. In the second series 3 concentrations of each sample and of rotenone were run, with 15 tests at each concentration. The average mortalities obtained are shown in Table 1.

The concentration of each extract and of rotenone which would have given a 50 per cent mortality was determined graphically. When percentage mortality was plotted against the reciprocal of concentration, the curves obtained were more nearly straight than when mortality was plotted directly against concentration, and for this reason the former method was used. In two cases in the first set (rotenone and No. 674) it was necessary to extrapolate to obtain the 50 per cent value, since the average mortality at the lowest concentration used was above 50 per cent. Figure 38, A, illustrates the curves obtained for Nos. 401, 594-B, 686-A, and for the rotenone standard run with them. The values for concentration at 50 per cent mortality are given in Table 1. By dividing this value for each sample into the value for rotenone run simultaneously with that sample, there was obtained, for each plant material, a figure which expressed the total toxicity of the materials present in terms of equivalent rotenone as tested against house flies. This, of course, had to be done separately for each set; i. e., the figure for a sample in Set A was obtained by using the value for rotenone run with Set A, and similarly for a sample in Set B. In this way it was possible to eliminate the differences due to variation in the susceptibility of the flies and thus make the two sets of figures comparable. These values, which may be termed the "percentage of rotenone based on toxicity" (Table 2, column 3) were suitable for direct comparison with chemical determinations made on these plant materials.

It should not be construed from this that all the toxic material present is of equal toxicity with rotenone. Thus in the case of sample No. 524 the value for rotenone based on toxicity is 11½ per cent. This could be made up of the 2 per cent rotenone known to be present plus about 19 per cent other material with a toxicity half that of rotenone. The net result

TABLE 1. TOXICITY TO HOUSE FLIES OF VARIOUS ROTENONE-BEARING PLANTS AND OF ROTENONE

Sample No.	Material	Concentration of acetone extract[1]	Average mortality of flies after 3 days[2]	Concentration equivalent to 50 per cent mortality
		Mg. per cc.	*Per cent*	*Mg. per cc.*
Set A:				
401	Derris root	5	71.5	3.12
		4	60.6	
		3	48.2	
		2	19.3	
523	Derris root (*Deguelia elliptica*)	5	70.5	2.94
		4	66.6	
		3	48.9	
		2	30.0	
524	Derris root (*D. malaccensis*)	4	85.5	1.47
		3	71.4	
		2	63.9	
		1	27.2	
594-B	Derris root	4	83.0	1.47
		3	72.5	
		2	62.5	
		1	31.4	
584	Cubé root	4	77.8	1.64
		3	67.0	
		2	57.4	
		1	28.2	
674	Cubé root	6	73.0	2.94
		5	63.2	
		4	59.8	
		3	51.1	
686-A	Cubé root	3	81.6	0.95
		2	74.5	
		1	52.0	
		0.5	18.5	
627	Haiari stem	10	57.3	8.00
		8	52.1	
		6	38.4	
		4	22.2	
———	Rotenone	1	78.5	0.17
		0.5	69.4	
		0.25	57.5	
———	Acetone check	—	2	
Set B:				
2217-M-1	Derris root	2	80.5	0.80
		1	61.8	
		0.5	15.7	
2217-P-1	Derris root	2	75.2	1.25
		1	38.4	
		0.5	4.8	
2218-H-1	Cubé root	2	77.3	1.08
		1	46.5	
		0.5	9.9	
2218-M-1	Cubé root	2	71.3	1.39
		1	32.6	
		0.5	5.4	
1927	*Gracca virginiana* root	16	70.5	11.1
		12	55.2	
		8	25.1	
——	Rotenone	0.25	69.8	0.12
		0.125	52.0	
		0.0625	14.9	

[1]Milligrams of plant material equivalent to 1 cc. of diluted extract, or milligrams of rotenone in 1 cc. of solution.
[2]Set A, 12 tests; set B, 15 tests.

TABLE 2. CHEMICAL DETERMINATIONS ON VARIOUS ROTENONE-BEARING PLANTS IN RELATION TO THEIR TOXICITY TO HOUSE FLIES[1]

Sample No.	Material	"Rotenone" based on toxicity	Carbon tetrachloride extraction: Rotenone	Carbon tetrachloride extraction: Total	Acetone extraction: Total	Acetone extraction: Material by Gross-Smith test	Benzene extraction: Total	Benzene extraction: "Rotenone" based on methoxyl	Ether extraction: Alkali-soluble material
Set A:									
401	Derris root.....	5½	None	10.4	12.2	0.8	9.4	7.3	4.1
523	Derris root (*Deguelia elliptica*)	6	1.1	11.8	12.0	3.0	10.4	8.7	2.2
524	Derris root (*D. malaccensis*)...	11½	2.0	21.4	22.4	3.2	20.0	16.5	5.0
594-B	Derris root.....	11½	5.0	18.2	21.2	14.4	17.7	15.5	2.2
584	Cubé root.....	10½	4.1	18.7	18.2	11.0	17.3	14.0	2.2
674	Cubé root.....	6	0.8	13.8	14.1	3.0	13.0	9.1	3.8
686-A	Cubé root.....	18	12.1	24.9	25.4	18.6	24.8	21.0	2.5
627	Haiari stem.....	2	0.2	6.6	6.4	1.4	6.6	4.2	1.8
Set B:									
2217-M-1	Derris root.....	15	7.8	22.0	24.8	12.0	21.2	18.9	1.9
2217-P-1	Derris root.....	9½	3.6	20.5	22.4	5.4	18.5	15.3	4.3
2218-H-1	Cubé root.....	11	5.6	21.0	21.7	10.8	20.3	17.3	3.0
2218-M-1	Cubé root.....	8½	3.8	21.5	23.0	9.6	20.9	17.7	4.4
1927	*Cracca virginiana* root.....	1	0.27	4.6	5.1	0.8	4.1	2.5	0.5

[1]All values in percentage of original plant material.

in terms of material as toxic as rotenone would thus be 11½ per cent. There is little doubt that the toxic materials other than rotenone do have different toxicities, but for the sake of comparison it is convenient to consider the toxicity of a sample in terms of the toxicity of rotenone.

CHEMICAL DETERMINATIONS.—Some of the chemical determinations made on these samples are given in Table 2. All these determinations were made within a few months after the toxicity values were obtained, thus eliminating the effects of possible decomposition on storage of some of the first set of roots.

Carbon tetrachloride extractions for determination of the rotenone content were made by the published method (*5*), with several slight modifications designed to give more complete extraction. Acetone and benzene extracts were prepared by Soxhlet extraction of 10 to 20 gram samples for 7 to 8 hours. The authors are indebted to Mr. C. R. Gross for making determinations by the Gross-Smith colorimetric method (*3*) on the acetone extracts. Methoxyl determinations were made on the dried benzene extracts by the modified Vieböck and Schwappach method (*2*), and the results were calculated to material having the same methoxyl content as rotenone. This value is significant, since all the known naturally occurring compounds of the rotenone group have approximately the same methoxyl content as rotenone. These values averaged about 10 per cent lower than those made on acetone extracts, and, since benzene is known to be a good solvent for rotenone and related compounds, these smaller methoxyl values are probably the better indication of the material present which is chemically similar to rotenone. In order to get a rough estimate of the toxicarol content of these samples, ether extracts were treated with dilute aqueous alkali. The alkaline layer was then acidified, extracted with ether, and the extract evaporated and weighed, to give the "alkali-soluble material." This procedure is based on the recent work of Haller and La Forge (*4*). Details of the methods

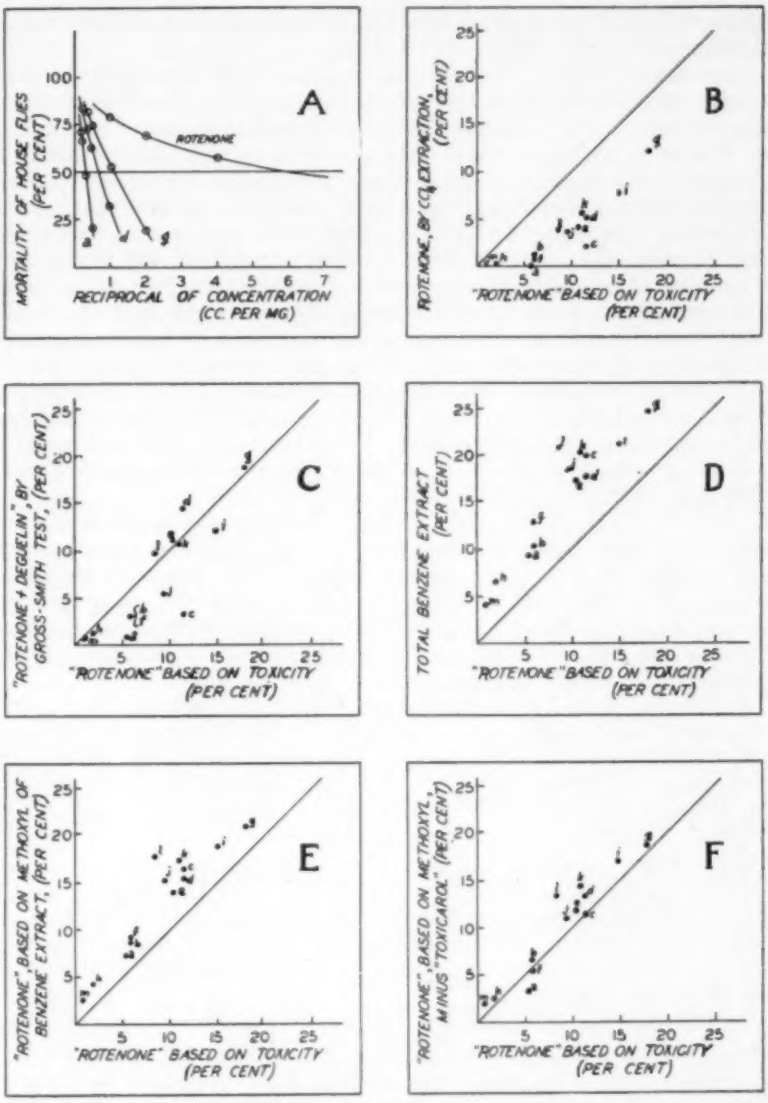
A
MORTALITY OF HOUSE FLIES (PER CENT)
ROTENONE
RECIPROCAL OF CONCENTRATION (CC. PER MG)
B
ROTENONE, BY CCl_4 EXTRACTION, (PER CENT)
"ROTENONE" BASED ON TOXICITY (PER CENT)
C
"ROTENONE + DEGUELIN," BY GROSS-SMITH TEST, (PER CENT)
"ROTENONE" BASED ON TOXICITY (PER CENT)
D
TOTAL BENZENE EXTRACT (PER CENT)
"ROTENONE" BASED ON TOXICITY (PER CENT)
E
"ROTENONE", BASED ON METHOXYL OF BENZENE EXTRACT, (PER CENT)
"ROTENONE" BASED ON TOXICITY (PER CENT)
F
"ROTENONE", BASED ON METHOXYL, MINUS "TOXICAROL" (PER CENT)
"ROTENONE" BASED ON TOXICITY (PER CENT)

Fig. 38—Chemical composition of rotenone-bearing plants vs. effectiveness of their acetone extracts against house flies: A, Typical curves of mortality vs. reciprocal of concentration; B, Rotenone vs. toxicity; C, "Rotenone + deguelin" vs. toxicity; D, Total benzene extract vs. toxicity; E, "Rotenone," based on methoxyl, vs. toxicity; F, "Rotenone," based on methoxyl, minus "toxicarol" vs. toxicity.

Key to Samples: a = No.401; b = No.523; c = No.524; d = No.594-B; e = No. 584; f = No. 674; g = No. 686-A; h = No. 627; i = No.2217-M-1; j = No.2217-P-1: k = No.2218-H-1; l = No. 2218-M-1; m = No.1927.

used, as well as the results of additional determinations on these samples, will be contained in a later article.

COMPARISON OF TOXICITY AND CHEMICAL COMPOSITION.—In order to compare the toxicity of these rotenone-bearing plants with their chemical composition, the values for "rotenone based on toxicity" as abscissas were plotted against the values obtained by the chemical determinations as ordinates, the same scale being used for both sets of values. The most desirable chemical determination would, of course, be one which gave a value about equal to that based on toxicity. Points such as this when plotted as described would fall on a line at an angle of 45° to the x-axis and passing through the origin. Such a line may then be used as an approximate graphic criterion of the comparisons of toxicity and chemical composition. In making these comparisons, it must be kept in mind that the toxicity values are valid only for the conditions of 50 per cent mortality. If another percentage mortality had been selected as a criterion, the values obtained would have been somewhat different, but would have maintained the same relative order. The 50 per cent point was used because many entomologists have accepted it as the most suitable point at which to make comparisons.

Figure 38 (B, C, D, E, and F) shows these plots for several of the chemical determinations. Rotenone alone (Fig. 38, B) did not account for all the toxicity in any of the samples tested. This was most striking in the cases of No. 401 with no rotenone, and No. 524 with only 2 per cent rotenone. It will be noted that, with the exception of these two samples, there is a fair degree of correlation between rotenone and toxicity, but in general only about half the toxicity is accounted for.

The values by the Gross-Smith test (Fig. 38, C), considered at present to represent total rotenone and deguelin, in general showed fair agreement with the toxicity, with the marked exceptions of Nos. 401 and 524. An average line drawn through the points, even with the exception of Nos. 401 and 524, however, would indicate the results in general to be somewhat lower than the toxicity values.

On the other hand, all the values for total benzene extractives were definitely higher than those for toxicity. (Fig. 38, D). This means that benzene extracts either some nontoxic materials or materials not equally as toxic as rotenone. The same reasoning applies to the carbon tetrachloride and acetone extracts, since they are (with one exception) greater than the benzene extracts.

Values based on the methoxyl content of the benzene extracts were higher than the toxicity values. (Fig. 38, E). However, by subtracting the alkali-soluble material, which is principally toxicarol, from the foregoing values, a set of figures was obtained which agreed rather closely in general with the toxicity (Fig. 38, F), although there were two or three samples in which the agreement was not very good.

Toxicarol in the form in which it has been isolated from plant materials is optically inactive and is practically nontoxic to insects. However, in the plant it may be optically active and toxic. It may be noted in this connection that, when the values for "toxicarol" are added to those by the Gross-Smith test (rotenone and deguelin), values are ob-

tained which are in substantial agreement with toxicity, although the correlation is not so good as with the set of figures described in the preceding paragraph. Several other combinations of the values resulting from chemical determinations gave fair agreement with toxicity.

The fact that apparent agreement with toxicity is obtained both when toxicarol is assumed to be nontoxic and other constituents of the extract are considered to account for the toxicity, and when the toxic materials are considered to be only rotenone, deguelin, and toxicarol stresses the necessity for a more detailed study of the individual root samples. This work should include the determination of the toxicities of various fractions of root extracts. Such a study should lead to estimates of the toxicity of the known compounds of the rotenone group in the form in which they occur naturally in the plant, and should also aid in the discovery of any additional toxic constituents which may be present.

RELATIVE TOXICITY OF DERRIS AND CUBÉ.—It might be pointed out that the samples selected included three pairs of derris and cubé roots of about the same rotenone and total-extractive content. Nos. 523 and 674 were originally of the same composition, and although both have undergone some decomposition they are about equal in toxicity to house flies. Nos. 594-B and 584 were originally similar, but after storage the cubé root was somewhat lower in rotenone content. This may account for the fact that the cubé sample is slightly less toxic than the derris. Nos. 2217-P-1 and 2218-M-1 are of about equal rotenone and total-extractive content, but the cubé is slightly lower in toxicity. Since these are results on only three pairs of samples and are complicated by the fact that some of the samples had decomposed, no general conclusions can be drawn as to the relative toxicity of derris and cubé roots.

SUMMARY AND CONCLUSIONS.—Results of toxicity to house flies of extracts of 6 samples of derris root, 5 samples of cubé root, 1 sample of haiari stem, and 1 sample of *Cracca virginiana* root were compared with the values obtained on these samples by certain chemical determinations.

The amounts of rotenone present in the samples were too low to account for all the toxicity. In more than half of the samples the figures by the Gross-Smith test, considered as representing the sum of rotenone and deguelin, agreed with the toxicity value, but in other samples they were lower. Total-extractive values were higher than toxicity, and values based on the methoxyl content of the extract were somewhat closer but were also too high. When an approximate value for toxicarol was subtracted from the methoxyl figures, the results agreed more closely with the toxicity figures in general than did the results of other determinations. However, it is impossible, on the basis of the present results, to recommend unreservedly any one of these chemical determinations as a measure of the insecticidal effectiveness of rotenone-bearing plants. Further work is needed on this subject, particularly along the line of a more thorough study of the individual constituents present in such plant materials.

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ARSENICAL SUBSTITUTES

I. CHEMICALS TESTED AS ARSENICAL SUBSTITUTES IN 1934[1]

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The Government restrictions on spray residues containing arsenic, lead and fluorine compounds has brought to the fore the need for a new, non-poisonous, efficient internal insecticide which could be safely applied on fruit and vegetables. Many chemists and entomologists employed by the various state agricultural experiment stations, federal government, insecticide manufacturers, etc., have been working on this problem and literally thousands of "new" and "old" chemicals in various combinations have been tested (1, 2, 3, 6, 7, 11, 12, 13, 14, 15, 16, 18). Some of these newly discovered internal poisons have developed into valuable adjuncts in the control of certain chewing insects such as nicotine tannate and nicotine bentonite combinations (4, 5, 9) against codling moth; derris mixtures (8, 10, 17) against beetles and caterpillars infesting vegetable and ornamental plants, and against house insects; and pyrethrum extracts (9) incorporated in oil against codling moth. While each one of these insecticides is functioning in the control of one or more species of chewing insects, none compares with arsenic in cheapness, in efficiency, in its inclusiveness for the general control of chewing insects. At present, arsenicals are still our outstanding, most economical, most reliable stomach poisons. After all the concentrated efforts of a host of research workers thruout the world for a period of over 10 years, we are still searching for the unknown. This may suffice to illustrate the complexity of the problem at hand. It is comparatively simple to find a chemical toxic to insects. It is, however, extremely difficult to find a chemical which should kill insects and should not be injurious to plants; should not be toxic to animals and man. Perhaps, had the efforts among the workers in this problem been more concentrated; had we had

[1]Paper of the Journal Series, New Jersey Agricultural Experiment Station, Department of Entomology.

opportunities to get together more often and exchange ideas; had we had some regulatory means of avoiding duplication of tests with the same chemicals, we might solve this problem sooner.

As matters stand today, each worker in this field merely reports from time to time on his tests with some chemicals. In this paper results with 87 chemical compounds are described.

METHODS OF TESTING.—When a large number of chemicals has to be tested in a comparatively short period of time it is most essential to employ a method which is simple in its operation and non-time consuming. Of the various methods in vogue for testing stomach poisons, the application of the chemical as a dust on foliage was found most convenient for preliminary testing. The procedure is as follows. One part of the chemical, whether liquid or powder, was thoroughly mixed with 19 parts of an inert carrier such as talc. The dust mixture was then applied, by the aid of a suitable salt shaker, on both sides of the leaf until uniformly covered. The excess dust was carefully shaken off from the leaf, so that a thin uniform coat remained. This precaution was necessary in order to avoid as much as possible external contact between the dust and the insect, which might cause some irritation to the insect and prevent it from feeding on the dusted foliage. The leaves, thus treated, were transferred to small beakers and several caterpillars placed on them. The mouth of the beaker was kept covered with cheese cloth fastened by a rubber band. The insects used for the preliminary tests consisted of silk moth larvae (*Bombyx mori*) in the third instar. The insects were raised in the laboratory on mulberry leaves, grown in the greenhouse from January to June, and in the field during the remainder of the growing season. For the greenhouse growth young mulberry trees of the ornamental drooping variety (*Morus alba* Linn.) were first forced outdoors by freezing and then transplanted in wooden buckets in late December or early January and placed in the greenhouse. Within a month from the time of planting there was usually enough growth of young foliage and berries to feed the newly hatched larvae.

When the preliminary tests with a chemical show appreciable toxicity or about 50 per cent mortality, the tests are immediately repeated on the same insect, using dusts and sprays containing various proportions of the chemical. If corroboration of the results from the preliminary tests is obtained, more extensive tests on other chewing insects available during the time of the experiment, are conducted in the laboratory, greenhouse, field or wherever the insects can be found. In all the preliminary laboratory tests, the toxicity of the chemicals are compared with a dust mixture containing 5 per cent lead arsenate and 95 per cent talc or similar inert carrier. Previous experiments have shown that this arsenical mixture is sufficiently strong to kill 80 per cent or more of the third instar silk worms within 48 hours. Checks consisting of leaves dusted with talc only and blanks where no food is given to the insects are run with each series of tests. Since certain chemicals emit some volatile materials which may act as repellents to insects, preventing them from eating the treated foliage, the blanks offer a simple means of detecting whether the insects die from starvation or from contact with the volatile ingredients.

EXPERIMENTAL.—The chemicals selected for this experiment were practically insoluble in water. Most of them were either amorphous or crystalline, powdered to about 100 mesh fine, while some were in liquid form. The compounds were divided into the following 4 groups:

A. Inorganic compounds, consisting of the phosphates of barium, copper and manganese and ten salts of cadmium.

B. Alkaloids and their salts.

C. Organic compounds containing methyl (CH_3) or methoxyl (OCH_3) groups.

D. Miscellaneous organic compounds among which diphenyl arsenious acid and triphenyl arsine were also included for comparison with lead arsenate.

Each series of tests was continued for 3 days, making daily observations. From 5 to 15 insects were used for each preliminary test, depending on the abundance of silk worms in the third instar at the time the tests were started. In the laboratory where the experiments were conducted, the temperature ranged from 66 to 74°F., and the relative humidity varied from 45 to 70 per cent.

The results from the preliminary tests presented in Tables 1, 2, 3 and 4 bring out twelve non-arsenical chemicals which produced insect mortality ranging from 50 to 100 per cent and four chemicals showing high repellency to the silk moth larvae. For the convenience of the reader, the twelve compounds are re-enumerated in Table 5.

Since pentachlorophenol gave 80% mortality, cadmium oxide and cadmium hydroxide gave 85% and 100% mortality respectively, these three chemicals were selected for further testing on silk moth larvae and other chewing insects. In addition to repeating the tests on silk moth larvae, tests were also conducted on the adult confused flour beetle (*Tribolium confusum* Duv.), the tent caterpillar (*Malacosoma americana* Fab.) and larvae of the Japanese beetle (*Popillia japonica* Newm.). The tests on tent caterpillars were conducted in the following manner. Apple twigs were sprayed with the insecticide mixture and placed in bottles of water under cages. Caterpillars of the third and fourth instars were placed on the twigs soon after the spray material had dried up.

The tests on the confused flour beetles were conducted as follows. A mixture of 85% flour and 15% of the chemical to be tested was pre-

TABLE 1. TESTS WITH INORGANIC COMPOUNDS FROM GROUP 1 ON SILK MOTH LARVAE

Test No.	Name of chemical	Per cent dead in 3 days	Amount of feeding
34	Cadmium phosphate	75	much
35	Copper phosphate	0	much
36	Barium phosphate	0	much
69	Cadmium sulfide	50	much
70	Cadmium oxalate	65	much
71	Cadmium acetate	0	much
72	Cadmium salicylate	0	much
73	Cadmium hydroxide	100	much
74	Cadmium carbonate	0	much
75	Cadmium sulfate	40	much
76	Cadmium chloride	0	much
88	Cadmium oxide	85	much
38	Manganese phosphate	0	much
Check	Lead arsenate	100	little
Blank	None	0	much

pared. About 100 gm. of this mixture were placed in small jars provided with perforated lids to which 20 adult insects were transferred, using duplicates for each test.

The tests on Japanese beetle larvae were carried out in peat soil. About 200 gm. of soil were thoroughly mixed with various proportions of the chemical and placed in dark tumblers, covered with cheese cloth. Twenty beetles were transferred to each tumbler and kept in an open insectary, adding water as needed.

The data, presented in Table 6, fully corroborate the results from the preliminary tests to the extent that each one of these three chemicals

TABLE 2. TESTS WITH CHEMICALS FROM GROUP 2 CONSISTING OF ALKALOIDS AND THEIR SALTS, ON SILK MOTH LARVAE

Test No.	Name of chemical	Per cent dead in 3 days	Amount of feeding
27	Caffeine benzoate	0	much
29	Caffeine citrate	20	much
28	Caffeine hydroxide	15	much
26	Caffeine salicylate	30	much
54	Caffeine tannate	40	much
20	Cinchonine	60	considerable
22	Cinchonine hydrochloride	0	much
21	Cinchonine sulfate	0	much
23	Cinchonine salicylate	30	much
24	Cinchonidine	15	much
133	3.5-Dimethyl pyrazole	0	much
104	2.6-Dimethyl quinoline ethiodide	0	little
91	Diphenyl guanidine	60	none (repellent)
31	8-Hydroxy quinoline	0	little
53	Nicotine tannate	80	little
47	Piperazine	0	little
55	Piperidine	80	considerable
58	2-Quinoline	40	very little
57	Iso-Quinoline	60	very little (repellent)
64	Quinoline salicylate	30	much
65	Quinoline tartarate	0	much
25	Quinoidine	15	much
106	Tetramethyl benzidine	0	much
132	Veratroldehyde	0	much
Check	Lead arsenate	100	little
Blank	None	0	much

TABLE 3. TESTS WITH CHEMICALS FROM GROUP 3 CONSISTING OF ORGANIC COMPOUNDS CONTAINING METHOXYL (OCH_3) AND METHYL (CH_3) GROUPS, ON SILK MOTH LARVAE

Test No.	Name of chemical	Per cent dead in 3 days	Amount of feeding
49	0-Methoxy benzoic acid	0	much
51	2-Methoxy naphthol	0	much
85	6-Methoxy quinoline	0	none (repellent)
52	Methoxy trimethyl gallate	0	considerable
40	Dimethyl hydroquinone	0	little
92	P-Dimethylamine phenol oxalate	30	little
94	Dimethyl glyoxine	100	little
99	4-Dimethyl amino benzene 1-azo-1 naphthalene	0	much
122	P-Dimethyl amine	0	much
125	Dimethyl dihydro resorcinol	0	much
127	Dimethyl ammonium dimethyl dithiocarbonate	0	much
128	Dimethyl ether hydroquinone	0	much
135	P-Dimethyl amino benzaldehyde	0	much
139	P-Dimethyl amino azo benzene	0	much
39	Naphthol methyl ether	15	much
98	Tetramethyl thiouram disulfide	0	little
100	4-Dimethyl amino benzene 1-azo-2-napthalene	0	much
101	Tetramethyl diamino benzohydrol	0	much
129	Tetramethyl diamino diphenyl methane	0	little
141	Tetramethyl diamino benzophenone	0	much
107	Trimethyl gallic acid	0	much
138	Pentamethyl benzene	0	much
124	Resorcylaldehyde dimethyl ether	0	much
Check	Lead arsenate	100	little
Blank	None	0	much

TABLE 4. TESTS WITH MISCELLANEOUS ORGANIC COMPOUNDS FROM GROUP 4 ON SILK MOTH LARVAE

Test No.	Name of chemical	Per cent dead in 3 days	Amount of feeding
30	A-Amino caproic acid	0	much
43	Anisol	0	considerable
19	O-Anisidine	0	much
44	M-cresol methyl ether	0	much
45	P-Cymene	0	much
32	Diphenyl arsenious acid	100	little
41	Diphenyl amine	0	little
9	Dinitro naphthalene	0	much
10	Dinitro toluene	0	much
42	Guaical	0	much
46	O-Nitroanisol	28	none (repellent)
50	Iodoxy benzoic acid	0	much
102	2 2.3.4.4.-Pentachloro-1-keto-1.2.3.4 tetra hydro naphthalene	0	little
130	Pentachlorophenol	80	considerable
140	Phenenthreen	0	much
2	Monobenzyl P-amino phenol	0	little
93	Triphenyl phosphate	20	little
95	Triphenyl arsine	60	much
103	Tetrachlorophthalic acid	0	much
105	Triphenyl stibine	0	much
108	Triphenyl chloromethane	0	much
121	Triphenyl bismuthine dichloride	0	much
123	Triphenyl bismuthine	0	much
131	1.3.5 triphenyl benzene	0	much
134	Tri-P-cresyl phosphate	0	much
136	Tri-O-phenyl-phenyl phosphate	0	much
137	Triphenyl methane	0	much
8	Trinitro naphthalene	0	much
Check	Lead arsenate	100	little
Blank	None	0	much

TABLE 5. NON-ARSENICAL CHEMICALS SHOWING 50 PER CENT OR MORE MORTALITY AND REPELLENCY TO SILK MOTH LARVAE

Test No.	Chemical used	Per cent dead in 3 days	Repellency observed
73	Cadmium hydroxide	100	none
88	Cadmium oxide	85	none
34	Cadmium phosphate	60	none
69	Cadmium sulfide	50	none
70	Cadmium oxalate	65	none
20	Cinchonine	60	none
53	Nicotine tannate	80	none
91	Diphenyl guanidine	60	repellent
130	Pentachlorophenol	80	none
85	6-methoxy quinoline	0	highly repellent
46	O-nitroanisol	0	highly repellent
57	Iso-quinoline	60	highly repellent
Check	Lead arsenate	100	none
Check	Untreated leaves	0	none
Blank	No food given	0	———

possesses high toxicity to silk moth larvae, even more pronounced when applied as a spray than as a dust. The two cadmium salts were found highly toxic also to the tent caterpillar and the confused flour beetle, but non-toxic to the larvae of the Japanese beetle.

PLANT INJURY.—Following the experiments on insects, tests were conducted on several species of plants in order to determine the tolerance of foliage to the above three chemicals. The following plants were sprayed with various concentrations of the chemicals: apple, peach, raspberry, cabbage, pepper, tomato, sweet peas, eggplant, cucumber, string beans and lima beans. Pentachlorophenol at dilutions of 1:4000 or lower injured foliage of all the above plants. Both, cadmium hydroxide and cadmium oxide produced no noticeable injury at concentrations of 0.25% or lower, while at higher concentrations distinct yellowing of leaves resulted to peach, apple and lima bean plants and no injury to the other plants tested.

TABLE 6. TOXICITY OF PENTACHLOROPHENOL, CADMIUM HYDROXIDE AND CADMIUM OXIDE TO CHEWING INSECTS

Chemical tested	Applied as	Per cent chemical in mixture	Spreader or carrier	Insect used	No. of insects per test	Per cent dead after: 2 days	3 days	10 days	15 days	Remarks
Cadmium hydroxide	Dust	5.00	Talc	Silk moth larvae	59	56	82	—	—	——
Cadmium hydroxide	Spray	0.50	Skim milk	Tent caterpillar	30	100	—	—	—	——
Cadmium hydroxide	Spray	0.37	Skim milk	Tent caterpillar	50	100	—	—	—	——
Cadmium hydroxide	Spray	0.25	Skim milk	Tent caterpillar	30	90	100	—	—	——
Cadmium hydroxide	Spray	0.125	Skim milk	Tent caterpillar	30	70	80	—	—	——
Cadmium hydroxide	Dust mixture	15.00	Flour	Confused flour beetle	40	0	0	100	—	——
Cadmium hydroxide	Soil mixture	1.00	Peat	Japanese beetle larvae	20	0	0	0	0	Pupated 2 mo. later
Cadmium oxide	Dust	5.00	Talc	Silk moth larvae	30	0	100	—	—	——
Cadmium oxide	Spray	0.37	Skim milk	Tent caterpillar	30	100	—	—	—	——
Cadmium oxide	Spray	0.25	Skim milk	Tent caterpillar	30	60	100	—	—	——
Cadmium oxide	Spray	0.125	Skim milk	Tent caterpillar	30	30	80	—	—	——
Cadmium oxide	Dust mixture	15.00	Flour	Confused flour beetle	40	0	0	50	100	——
Cadmium oxide	Soil mixture	1.00	Peat	Japanese beetle larvae	20	0	0	0	0	Pupated 2 mo. later
Lead arsenate	Soil mixture	0.50	Peat	Japanese beetle larvae	20	0	100	—	—	——
Pentachlorophenol	Spray	0.25	Skim milk	Silk moth larvae	30	100	—	—	—	——
Pentachlorophenol	Spray	0.10	Skim milk	Silk moth larvae	20	100	—	—	—	——
Pentachlorophenol	Spray	0.05	Skim milk	Silk moth larvae	20	70	80	—	—	——
Pentachlorophenol	Spray	0.025	Skim milk	Silk moth larvae	20	30	50	—	—	——
Check	Spray	None	Skim milk	Silk moth larvae	20	0	0	—	—	——
Check	Spray	None	Skim milk	Tent caterpillar	30	0	0	—	—	——
Check	Dust mixture	None	Flour	Confused flour beetle	40	0	0	0	0	——

SUMMARY.—Experiments with several groups of chemicals were conducted on chewing insects. Of the 74 organic chemicals tested, pentachlorophenol, cinchonine, nicotine tannate and diphenyl guanidine were found to possess high toxicity to silk moth larvae; methoxy quinoline, diphenyl guanidine, iso-quinoline and O-nitroanisol possess distinct repellency to silk moth larvae. Of the 13 inorganic chemicals tested cadmium oxide and cadmium hydroxide proved highly toxic to silk moth larvae, tent caterpillars and confused flour beetles but showed no toxicity to larvae of the Japanese beetle. Tested on plants, pentachlorophenol produced injury in high dilutions, while the two cadmium salts produced moderate injury to certain plants in concentrations of 0.50% or higher and no noticeable injury to any one of the plants tested at concentrations of 0.25% or lower.

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THE COLLECTION AND ANALYSIS OF DATA ON THE VALUE OF NON-ARSENICAL INSECTICIDES FOR THE CONTROL OF CABBAGE WORMS

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The literature on the value of insecticides for the control of cabbage and cauliflower worms shows a great variation in the methods used in collecting and interpreting the data. This has resulted in confusion and inability in some instances to compare results of different workers. Yield cannot be considered as a basis for evaluating insecticidal treatment since these insects do not affect yield as they do quality. Classification of the amount of injury at harvest time is beset with personal error. Experiments using either yield or classification of injury have to be carried a whole season, which adds seasonal factors, effect of number of treatments, and reinfestation. Another basis is a direct count of insects. This method has been used by various workers but in no uniform way. Some have counted worms on treated plots in comparison with a single untreated plot often too remote to be comparable. Others have se-

lected plants at random in treated and untreated plots, often counting a different random selection for a second count.

The data presented in this paper show a method in which individual plant counts before and after treatment are analysed statistically. A count before treatment followed by another shortly afterwards deals largely with the strength of material and its effect upon the insect. Other control recommendations, such as number of treatments necessary, are secondary and cannot be determined until the strength of material and its effect upon the insect is known. The number of treatments necessary may vary with the season, but the direct effect of the insecticide upon the insect will be almost constant. The 1934 data presented here allow reliable analyses only of the results on *Ascia rapae* Linne. *Autographa brassicae* Riley was rarely present and *Plutella maculipennis* Curtis present on some plots only in numbers sufficient to give indications. Almost all tests were made on cabbage but the same strengths of materials should be effective on the same insects on cauliflower.

The data discussed were collected upon the basis of count before and after treatment. All applications were in dust form. The diluent was Celite FC, a diatomaceous earth 5 per cent of which is coarser than 150 mesh and 10 per cent coarser than 325 mesh. The insecticides which include powdered derris, cube and pyrethrum, Paris green, cryolite, calcium arsenate, and lead arsenate, were diluted on the basis of the manufacturers' analyses. As a precaution against errors on account of possible marked deterioration samples taken at the end of the season are being analysed. Dusts were prepared in a mixer of ball mill type that was easily cleaned. The mill was operated for five minutes except where extracts were used, these being mixed for ten minutes. Field plots were laid out in a compact block for each group of treatments. A block was about thirty feet square so that the plots within a block are all comparable. Each plot consisted of a row long enough to include a little more than 20 plants. Between plots an untreated row, about 5 feet of space, was left to overcome the effect of drifting dust. Several plants were left on the ends as buffers and to permit having the duster going at a constant speed by the time of starting to dust the actual count plants. The plants were examined before treatment and the number of larvae of each of the cabbage plots recorded. The number of plots within a block was limited to the number that could be counted and treated in one day, usually 4 but sometimes as many as 5 or 6 in favorable fields. Applications were made in the evening using a rotary type duster, the Root Hand Duster, set at twenty. The operator walked at approximately two miles per hour; each row was dusted once and no attempt was made to cover anything but the head, altho the foliage was usually quite well covered. The rate of application for all plots within a block was constant. The rate per acre varied with the distance between rows and other factors, but did not exceed 10 pounds. Treatments were located at random in blocks. A second count of worms was made three days after treatment on the same plants. Later in the season when the temperature was lower, the time was extended to make certain the materials had time to take effect. As far as time permitted series of tests were replicated. More

replication and another season's work would have sampled the varying conditions more fully and permitted more conclusive results.

The differences obtained were the result of both chance error and the effect of the insecticide applied. Chance errors were caused by fluctuating factors and might have included counting errors, migration, disease, parasitism, predators, pupation, and hatching. Statistical analysis has been used to evaluate the chance error. "Student's" method of paired comparisons[1] was adopted since it is useful when small numbers of samples are taken. Twenty plants were used because the use of forty did not reduce the error enough to justify the additional labor. Since the error in per cent of the mean is high the use of much larger numbers of plants would possibly bring out differences that are not evident when 20 plants are used. From an entomological standpoint in this problem pairing was best done by counts on the same plant before and after treatment. This is essentially the "per cent kill" long used in entomology but, in addition a standard error is obtained to measure the variability of the mean.

Data from a sample plot is presented dealing with *Ascia rapae* Linne. The dust used was .18 per cent pyrethrins, using pyrethrum powder with Celite FC as a diluent.

Plant	Larvae after treatment	Larvae before treatment	d	d^2
1	2	4	2	4
2	3	9	6	36
3	2	3	1	1
4	0	2	2	4
5	1	11	10	100
6	2	9	7	49
7	4	3	−1	1
8	0	8	8	64
9	1	7	6	36
10	4	5	1	1
11	3	13	10	100
12	3	7	4	16
13	3	4	1	1
14	1	14	13	169
15	3	7	4	16
16	3	8	5	25
17	0	3	3	9
18	1	13	12	144
19	0	6	6	36
20	2	4	2	4
			103	d^2 816
			−1	
			$\Sigma d = 102$	

$$d_{\bar{x}} = \frac{\Sigma d}{N} = \frac{102}{20} = 5.1$$

[1]1929 Goulden, C. H. Statistical methods in agronomic research, Canadian Seed Growers' Association, pp. 19 and 26.

1923 Love, H. H. The importance of the probable error concept in the interpretation of experimental results. Journal American Society of Agronomy 15: 217–224.

$$SD = \sqrt{\frac{\Sigma d^2}{N} - d\bar{x}^2} = \sqrt{\frac{816}{20} - (5.1)^2} = 3.84$$

$$\text{SE of mean difference} = \frac{SD}{\sqrt{N-1}} = \frac{3.84}{4.36} = .88$$

Mean difference = 5.1 ± .88

d is the difference between the number present before treatment and the number present after.

Σ is summation.

$d\bar{x}$ is mean difference.

N is the number of sample pairs, namely 20.

It is necessary to determine whether the difference between treatment and no treatment are statistically significant. A suitable test known as the "t" test has been proposed by Fisher,[1] $t = \frac{d\bar{x}}{SE} = \frac{5.1}{.88} = 5.79$

This "t" value must be transformed to probability by use of Fisher's "t" table, in which "n" corresponds to the number of degrees of freedom, the number of values which can vary. In this case, the number of degrees of freedom is N—1, or 19. The "t" value for the 5 per cent point, which corresponds to odds of 19:1, is 2.093 for this example. Should a more conservative level, such as the 1 per cent point, be chosen, the odds would be 99:1. The "t" value for P = 0.01 is 2.861. The "t" actually obtained equals 5.79 indicating that the odds are greater than 99:1 that the difference is due to the treatment. Significance at this point is determined by consistency of the differences. Care must be taken to be certain that the differences arose from the treatment and not from other causes. "Student's" method is applicable to other types of entomological work but good judgment must be used in applying significances. A significant difference might not in all cases be caused by some particular treatment. In some types of work a significant difference in population might occur because of a period of unfavorable weather rather than because of any treatment that was applied. Not always do treatments appear significant and the treatment need not be compared further. A 25 per cent calcium arsenate and 75 per cent Celite FC dust gave a "t" value of .07 which is not significant. This treatment was not effective.

A series of several plots may be run together in a block and a mean reduction and standard error obtained for each plot. A mean initial population is obtained by dividing the total number present before treatment by 20.

Treatment	Mean Reduction and SE	P	Initial Mean Population	Mean % Kill and SE
.5% rotenone, cube powder	5. ± .71	<.01	5.85	85.4 ± 12.1
.18% pyrethrins, powder...	5.1 ± .88	<.01	7.	72.8 ± 12.5
.5% rotenone, derris powder.....	5.3 ± .94	<.01	7.95	66.6 ± 11.8
.18% pyrethrins, kerosene extract.....	3.45 ± .65	<.01	5.5	62.7 ± 11.8

[1]1930 Fisher, R. A. Statistical methods for research workers. Third edition, pp. 103–147, and 139.

The mean per cent kill and its standard error is obtained by dividing the mean reduction and its error by the initial mean population. This is made necessary by the fact that the populations to begin with varied on the different plots so that the mean reduction is the result of the effect of population and the insecticide. The differences in the mean reductions cannot be used directly for comparison because it is impossible to assign a value to the two factors causing the difference. Per cents offer a common unit of expression. The method of obtaining the mean per cent kill and its standard error preserves the same relation between the two as existed in the mean reduction and its standard error. The mean per cent kill varies and it remains to be seen whether these differences are greater than the chance error which occurs.

Treatment	Mean % Kill
.5% rotenone, cube powder	85.4 ± 12.1
.5% rotenone, derris powder	66.6 ± 11.8
Difference	18.8 ± 16.9

$$d_e = \sqrt{SE_1^2 + SE_2^2} = \sqrt{12.1^2 + 11.8^2} = 16.9$$

$D/SE = \frac{18.8}{16.9} = 1.11$ Not significant if 2 is taken as the level of significance.

d_e is the error of the difference

D/SE is the difference divided by the error of the difference

If this ratio of D/SE is 2 the odds are 19:1 in favor of the difference not being due to chance error. In this case 1.11 is not great enough that the difference can be considered significant. Therefore derris and cube under the conditions of the experiment can be considered as equally effective. Calculated in the same way pyrethrum powder, derris and cube are not significantly different at the strengths used. The pyrethrum powder and kerosene extract are not significantly different at .18 per cent pyrethrins.

NON-ARSENICALS COMPARED.—A series of three plots was run using pyrethrum, derris, and cube powders. The diluted dusts contained .18 per cent pyrethrins or .5 per cent rotenone. The treatments are compared with some indicated standard.

Treatment	Mean Reduction and SE	P	Initial Mean Population	Mean % Kill and SE	D/SE
Derris.....	4.6 ± .89	<.01	6.15	74 7 ± 14.4	Standard
Cube.....	2.5 ± .36	<.01	3.6	69.4 ± 10	.30
Pyrethrum...	4. ± .75	<.01	5.9	67.7 ± 12.7	.36

There is no significance between treatments since there is no significance between the extremes. This series shows that .18 per cent pyrethrins in powder, .5 per cent rotenone in derris powder, and .5 per cent rotenone in cube powder are of equal efficiency.

NON-ARSENICALS COMPARED WITH EACH OTHER AND WITH PARIS GREEN.—A series of four plots was run, using .18 per cent pyrethrins from pyrethrum powder, .5 per cent rotenone from derris powder, .5 per cent rotenone from cube powder, and 12.5 per cent Paris green. The treatments are compared to the indicated standard.

Treatment	Mean Reduction and SE	P	Initial Mean Population	Mean % Kill and SE	D/SE
Paris green...	5.55 ± .96	<.01	6.7	82.8 ± 14.3	Standard
Pyrethrum...	3.8 ± .67	<.01	5.2	73. ± 12.8	.51
Cube.....	5.6 ± 1.01	<.01	8.15	68.7 ± 12.3	.74
Derris.....	5.65 ± .79	<.01	9.6	58.5 ± 8.2	1.45

There is no significance in any comparison. In this series of plots .18 per cent pyrethrins from pyrethrum powder, .5 per cent rotenone from derris powder, .5 per cent rotenone from cube powder, and 12.5 per cent Paris green are of equal value in the control of *Ascia rapae* Linne.

DILUTION OF DERRIS POWDER.—Three separate series of plots were run. Each series has to be a unit to itself. The conclusions that may be drawn from each series may be summed up in a final conclusion but no direct comparison of per cent kill in one series should be made with any other series. The final conclusion should merely summarize the three separate conclusions obtained from the three series.

Treatment	Mean Reduction and SE	P	Initial Mean Population	Mean % Kill and SE	D/SE
.4% rotenone	7.15 ± .92	<.01	9.25	77.2 ± 9.9	Standard
.3% rotenone	4.5 ± .69	<.01	6.05	74.3 ± 11.4	.19
.1% rotenone	3.7 ± .82	<.01	5.45	67.8 ± 15.	.54
.2% rotenone	3.2 ± .59	<.01	4.75	67.3 ± 12.4	.62

There is no significance shown and .1 per cent rotenone is as effective as .4 per cent in this series.

Treatment	Mean Reduction and SE	P	Initial Mean Population	Mean % kill and SE	D/SE
.5% rotenone	4.6 ± .89	<.01	6.15	74.7 ± 14.4	Standard
.4% rotenone	3.8 ± .54	<.01	5.1	74.5 ± 10.5	.01

There is no significant difference between .5 per cent and .4 per cent rotenone in this series.

Treatment	Mean Reduction and SE	P	Initial Mean Population	Mean % Kill and SE	D/SE
.6% rotenone	3.5 ± .55	<.01	4.7	74.4 ± 11.7	Standard
.3% rotenone	3.4 ± .61	<.01	5.45	62.3 ± 11.1	.75
.4% rotenone	2.75 ± .65	<.01	4.45	61.7 ± 14.6	.67
.5% rotenone	2.1 ± .35	<.01	3.55	59.1 ± 9.8	1.00

There is no significance and the extremes of .3 per cent rotenone and .6 per cent rotenone are not different in this series.

The summary of the three series shows that there is no difference in effectiveness between the dilutions from .6 per cent to .3 per cent. Also .5 per cent and .4 per cent are not significantly different. The results indicate that a series with a greater range in strengths would have been desirable. Possibly the numbers of samples are too small to detect the differences if such existed.

MORNING AND EVENING APPLICATIONS COMPARED.—Pyrethrum powder at .18 per cent pyrethrins was applied morning and evening under good dusting conditions.

Treatment	Mean Reduction and SE	P	Initial Mean Population	Mean % Kill and SE	D/SE
Evening.....	4.35 ± .69	<.01	5.45	79.8 ± 12.6	Standard
Morning.....	3.55 ± .57	<.01	5.6	63.3 ± 10.1	1.02

In this series the morning and evening applications of .18 per cent pyrethrins are not significantly different.

Cube powder at .5 per cent rotenone was compared in morning and evening applications under the same conditions as the pyrethrum.

Treatment	Mean Reduction and SE	P	Initial Mean Population	Mean % Kill and SE	D/SE
Morning.....	2.75 ± .55	<.01	4.65	59.1 ± 11.8	Standard
Evening.....	3.15 ± .72	<.01	6.5	48.4 ± 11.	.66

Morning and evening applications of .5 per cent rotenone cube are not significantly different in this series.

SUMMARY.—The application of "Student's" method of paired comparisons to a certain type of entomological problem is shown. Details of method and calculation are presented. In problems where numbers of samples must be small and opposing factors can be logically paired, "Student's" method may find use.

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THE CONTROL OF SOME ECTOPARASITES OF LABORATORY RATS BY ATOMIZED PYRETHRUM EXTRACTS IN OIL[1]

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Rats used in biological laboratories are frequently infested with Arthropod parasites which feed upon and annoy not only the rats but in some cases, the people working with them. It has been difficult, where it has been possible, to control these pests principally because no satisfactory control methods have been available. In the investigation reported here it was found that pyrethrum extract sprayed upon rats in an atomized oil was an easily applied, efficient insecticide, and that the treatment did not affect the rats adversely.

The usual animal dips have not been found available for this purpose. Rats reared under laboratory conditions are very sensitive to abrupt changes in environment and dipping in aqueous solutions of insecticides has frequently been followed by pneumonia and other respiratory diseases. Some dusts, particularly finely ground pyrethrum flowers, have

[1]Published with the permission of the Director of the Wisconsin Agricultural Experiment Station.

been used successfully. They are effective against the parasites and are not known to have injured the animals. Their use in laboratories containing many animals is seldom feasible because of the difficulty of application. Dusts must be thoroughly and evenly rubbed into the fur of the rats in order to reach the parasites which are usually found very close to, or just under the skin.

It has been found (1) that derris dust, when used undiluted, is very effective against the parasites but may not be used because of its toxicity to the animals when licked from their coats. Diluted with 80% tobacco dust this difficulty was overcome without reducing the effectiveness of the dust. Sodium fluoride has also been used both as a powder and as a dip to rid rats of external parasites. It is not to be recommended for this purpose, however, since it has been shown (2) to be definitely toxic to rats even in very small quantities.

Dusts and aqueous solutions are not satisfactory for the control, in occupied cages, of parasites which hide about the cages most of the time approaching the animals only to feed. Aqueous solutions leave the cages wet and uncongenial to the animals for a long period. At the same time, unless the cages are completely soaked with the solution, the insecticide frequently fails to penetrate to all of the hiding places of the parasites. Dusts also fail to reach parasites secreted in remote hiding places about the cage. A satisfactory control therefore would have to kill the parasites in and about the cage as well as on the animals without injuring the animals or rendering the cages untenable for them.

Pyrethrum extract dissolved in a highly refined petroleum distillate, applied by atomization, appeared to possess the attributes necessary for the purpose. Pyrethrum is not known to be toxic to warm-blooded animals while previous experiments have indicated that the oil will not injure rats. The oil used penetrates readily due to its unusually low surface tension and evaporates quickly. The following experiment was conducted to test the efficiency of pyrethrum applied in this way.

MATERIALS AND PROCEDURE.—For the purpose of this experiment rats infested with sucking lice (*Polyplax spinulosa* Burm., identification courtesy H. E. Ewing, U. S. D. A.) were selected.[2] Both albino and hooded rats were used. Each test was made in duplicate. The sprays were applied with a De Vilbiss No. 15 atomizer under a constant air pressure of about 11 pounds. The atomizer (A) was equipped as shown in Figure 39 with a pressure gage (B) to detect any variation in air pressure and a tube (C) from which the spray was drawn into the atomizer. The rats were placed for spraying into a cylindrical screen wire cage 22.55 cm. by 26.87 cm. having a screen wire false bottom. Under these conditions the mist produced by the atomizer was not confined. Spray directed downward upon the rat was deflected upward by the solid cap over the bottom of the cage thereby wetting the underside of the animals. Nearly all of the rats used were immature.

When the animal to be treated was placed in the cage, the stop cock

[2]These rats were donated by Doctor Harry Steenbock of the Department of Agricultural Chemistry. Many thanks are due Doctor Margaret Irwin of the Steenbock Laboratory for assistance and many helpful suggestions.

FIG. 39.—This shows the arrangement of the atomizer (A) in relation to the pressure gage (B), the tube (C) into which the spray was placed for atomization, and the stop cock (D).

(D) was opened and held open until the accurately measured amount of oil placed in the tube had been drawn out and atomized into the cage. The time elapsed from the beginning of the spray until it had ended was determined with a stop-watch. Air pressure was obtained from a tank automatically held at a constant pressure.

The oil used in this experiment was a commercially produced, highly refined, saturated, petroleum distillate, 98% unsulphonable residue and 30–35 seconds viscosity, Saybolt test. The pyrethrum extract[3] used, also a commercial product, was an extraction of pyrethrum flowers, by the same oil, adjusted to 2.1% pyrethrins.

The amount of spray necessary to thoroughly wet a rat in the cage used was first determined. This was done by spraying the rats with successively larger amounts of the spray containing 6% of pyrethrum extract. It had been determined experimentally that this concentration was quickly lethal to the insects. Starting with 2 cc. the amount of spray was increased 1 cc. for each test until it was found that 5 cc. of spray killed practically all of the insects. Rats numbered 1a–5b inclusive were used for this purpose. It was then assumed that under these conditions 5 cc. of spray was ample to wet the animal sufficiently and was therefore the basic amount from which dilutions were tested. Duplicate tests were then made beginning with oil alone and increasing the

[3]The pyrethrum extract and oil were furnished by John Powell & Co., Inc., and L. Sonneborn Sons, Inc., both of New York City, respectively.

pyrethrum extract content 1% each time until 5% of the extract had been used. A ½% increase was tried between 1 and 2 per cent. The average time required to apply 5 cc. of the spray was 24.9 seconds ± 2.2. (Standard error of mean used in every case.)

In order to measure the effect of the treatment upon the rats, body weights were taken just before, 24 and 48 hours after spraying. The body temperature of the rats was also determined before, about three-fourths and five hours after spraying.

In order to determine the per cent of insects killed by the treatment, the rats were removed immediately after spraying to a cage similar to the one in which they were sprayed. Here they were retained without food about 5 hours over pieces of white paper cut to fit the cage. Dead lice which fell from the animals were quite easily seen on the white paper. If food had been placed in the cage it would have been scattered about by the animal thereby obscuring the lice. At the end of about 5 hours the rat was thoroughly brushed with a soft paint brush to remove all dead lice clinging to the hair. All of the dead lice were then counted. Several collections made in this way were placed in Petri dishes for observations as to recoveries. No recoveries were observed. At the end of this period food and water were given the animal which was not disturbed again for 24 hours when it was again thoroughly brushed and the dead lice counted. This procedure was repeated at the end of 48 hours. At the end of this time each rat was killed and wrapped in cotton batting. After about 24 hours the cotton was examined and all lice counted. It was assumed that by this time all living lice had left the animal. This assumption was verified by critical examinations of all of the carcasses.

The per cent efficiency of the spray was calculated by dividing the total number of lice removed into the number of lice killed. Similar data were taken for two rats, 6a and 6b, which were sprayed with 5 cc. of the oil without pyrethrum and 2 rats, 13a and 13b, which were completely immersed in the oil containing 2% of the extract. The data collected in the counts are presented in Table 1.

It was thought necessary to destroy the rats at the end of 48 hours in order to determine the number of lice left upon them. It was anticipated that reproduction or reinfestation would disturb the results if the animals were retained longer. Because of this no data are available on the effect of the treatment on these rats after 48 hours. In order to follow the results of both the spray and immersion treatment after the usual 48 hours, 6 additional rats, 4 males and 2 females were sprayed with, and six, 3 males and 3 females were immersed in the 2% solution. Only the reactions of the animal to the treatment were noted. It was found that of the sprayed animals, 3 lost weight the first day, the other 3 remained unchanged, and all resumed normal weight gaining after the 2nd day. The body temperature of the sprayed rats remained within the usual temperature range of normal rats during the several days they were under observation. Of the 6 rats which were immersed, 1 male died 5 days after treatment. A post mortem examination failed to reveal the cause of death. The other 5 animals suffered an average depression in temperature of 1.6° ± .27° one-half hour after treatment but had re-

TABLE 1. THIS TABLE SHOWS THE VARIOUS SPRAY COMBINATIONS USED AND THEIR EFFECT UPON THE BODY TEMPERATURE AND WEIGHT OF THE ANIMAL AS WELL AS EFFECTIVENESS AGAINST THE LICE. MADISON, WISCONSIN, 1934

Rat No.	Oil cc.	Per cent Pyrethrum	Body temperature in degrees Centigrade			Body weight, grams			Number of lice			
			Before spray	½ hr. after	5 hrs. after	Before	24 hrs. later	48 hrs. later	Dead	Live	Total	Per cent kill
1a	2	6.0	35.67	35.22	35.28	458.0	461.0	461.0	16	15	31	51.6
1b	2	6.0	35.17	35.22	35.00	410.5	411.0	408.0	117	48	165	70.9
2a	2	6.0	34.88	35.67	35.00	388.0	287.0	289.0	124	68	192	64.5
2b	2	6.0	37.50	37.55	37.55	272.5	273.0	273.0	40	43	83	48.2
3a	3	6.0	37.55	35.78	35.44	341.0	342.0	343.0	136	34	170	80.0
3b	3	6.0	35.11	35.44	36.89	296.0	297.0	297.0	815	180	995	81.9
4a	4	6.0	36.44	37.11	36.55	226.0	225.0	226.0	10	1	11	90.9
4b	4	6.0	35.22	37.44	36.89	271.5	270.0	270.0	146	69	215	67.9
4c	4	6.0	36.33	37.11	36.89	261.0	257.5	256.0	63	0	63	100.0
5a	5	6.0	37.44	37.89	37.00	258.0	259.0	261.0	40	0	40	100.0
5b	5	6.0	36.67	38.11	36.67	269.0	269.0	273.0	32	2	34	94.1
6a	5	00	38.33	38.00	36.22	233.0	240.0	243.0	7	2	9	77.7
6b	5	00	38.11	38.33	38.33	237.5	246.0	251.0	48	7	55	87.2
7a	5	1.0	37.78	38.79	37.89	228.0	228.0	234.0	4	1	5	80.0
7b	5	1.0	38.55	39.33	37.78	239.0	239.0	234.0	5	0	5	100.0
7c	5	1.0	37.44	38.66	38.00	239.5	240.0	245.0	3	1	4	75.0
7d	5	1.0	36.44	37.78	36.44	190.0	185.0	189.0	6	0	6	100.0
8a	5	1.5	37.11	37.44	38.00	270.5	268.5	264.0	22	16	38	57.8
8b	5	1.5	37.72	37.33	37.22	249.0	249.0	249.0	35	2	37	94.6
9a	5	2.0	36.67	37.55	37.66	226.0	236.0	247.5	39	0	39	100.0
9b	5	2.0	37.11	37.78	37.89	269.0	269.0	270.0	291	0	291	100.0
9c	5	2.0	38.44	37.89	37.78	271.0	209.0	188.0	28	0	28	100.0
9d	5	2.0	38.77	38.55	38.33	199.0	197.0	200.0	14	0	14	100.0
10a	5	3.0	37.00	38.44	38.00	228.0	234.0	234.0	18	0	18	100.0
10b	5	3.0	36.55	37.22	——	274.0	281.0	281.0	40	0	40	100.0
10c	5	3.0	37.66	38.77	38.72	173.0	171.0	176.0	13	0	13	100.0
11a	5	4.0	38.33	38.00	36.22	276.0	275.0	280.0	27	0	27	100.0
11b	5	4.0	38.11	38.33	38.33	286.0	285.0	289.0	12	0	12	100.0
12a	5	5.0	36.55	36.78	36.89	408.0	407.0	402.0	295	8	303	97.3
12b	5	5.0	38.00	38.61	37.89	285.0	283.5	275.0	27	0	27	100.0
13a	immersed	2.0	38.55	37.00	36.55	221.0	210.0	202.0	34	0	34	100.0
13b	immersed	2.0	39.22	37.84	37.78	215.0	201.0	197.0	19	0	19	100.0

turned to within the usual temperature level of healthy rats after 5 hours. All lost weight the first day after treatment but gained slowly after the 2nd day and by the 6th day had regained all lost weight.

Two additional rats were immersed in oil alone. No disturbance in temperature was noted in these rats. Both had resumed weight gaining after the third day.

A litter of 7 10-day old rats was sprayed also with 5 cc. of the 5.0% dilution to observe the effect of the treatment on very young rats. It was not possible to follow temperature reaction with the clinical thermometer used. The litter lost weight the 1st day but resumed gaining and had passed their before treatment weight the 2nd day. Another litter of 5 2-day old rats sprayed with 5 cc. of the 2% dilution showed no interruption in normal weight gaining. A litter of 7 3-day old rats reacted similarly under the same treatment.

No experiment was conducted to determine the most effective amount of pyrethrum extract needed to control bedbugs (*Cimex lectularius* Linné) in and about wooden rat cages with screen wire fronts and backs. It was found, however, that a 5% dilution of the extract sprayed on and into occupied cages would control the bedbugs without injuring the rats. This concentration was also effective against cockroaches and silver fish.

Eleven mites (Acarina) were found upon the treated animals. Nine had been killed by the treatments. Of these 7 had been treated with the 5.0% dilution, while 2 had been treated with the oil alone. The

living mites were found on animals after treatment with 4.0 and 5.0% dilutions.

Discussion of Data.—The figures presented in Table 1 show that under the conditions of this experiment, 5 cc. of the oil containing 2% or more of the pyrethrum extract sprayed upon a rat from a De Vilbiss No. 15 atomizer, at about 11 pounds pressure in the cage used, destroyed practically all of the body lice. When less than 2% of pyrethrum extract was used the kill was variable. Less than 5 cc. of the spray was not sufficient to effectively wet each rat. Five cc. of oil alone killed an average of 82.5% of the lice. Immersion in a 2% dilution destroyed all of the lice.

At the end of 48 hours 19 of the rats sprayed had returned to normal weight gaining while 8 had lost an average of 4.5 gms. ± 1.0 gms. the second day. In every case the effect of the treatment upon body weight and temperature is figured from the immediately before treatment condition of each animal. Two of the remaining 3 had not changed body weight while 1 gave birth and its records could not be used. Body temperatures in 24 of the 30 rats sprayed rose on the average .81° ± .11° during the ¾ hour period. The temperature of 6 fell an average of .37° ± .04°. About 5 hours after spraying, 16 still showed an average temperature rise of .67° ± .13°. Eleven had subnormal temperatures averaging .86° ± .23° below their before treatment temperature. Two rats had returned to normal. One record was lost.

Of the two rats which were immersed and destroyed after 48 hours 1 had lost 1.55 degrees body temperature and the other 1.38° at the end of ¾ hour. The temperature of the former had dropped .45° further at the end of 5 hours while the latter had lost .06° during the same period. At the end of 24 hours 1 had lost 11 gms. in body weight while the other had lost 14 gms. Twenty-four hours later they had lost a total of 19 and 18 gms. respectively.

The rats which had been sprayed with the 2% dilution and retained over a period of several days for observation as to the effect of treatment on body temperature and body weight suffered only a brief disturbance in weight gaining. Body temperatures were not disturbed beyond the normal range of healthy rats. The immersed rats of the retained group were more affected by the treatment. The temperature of these rats was considerably depressed and all lost weight for a longer period of time. Some internal disturbance was also present as evidenced by a protracted diarrhea and extensive irritation about the anus. Much of the hind legs, particularly the ental area and the feet, were also affected. Epilation and some desquamation were evident over the whole area which also showed extensive erythema.

Both immersed and sprayed rats attempted to rid their coats of the oil by licking and in this way swallowed much of the spray. Immersed rats had a heavier coating of the oil than sprayed rats. The former required from 3–5 hours in a well ventilated room at 75°F. before their coats were free from oil while the latter were quite dry in about one-half hour. Under these conditions it would be expected that the immersed animals would swallow more of the oil. This experiment does not demon-

strate whether the oil or the pyrethrum was responsible for the injury to the immersed rats.

SUMMARY.—Two per cent of an oil extract of pyrethrum adjusted to 2.1% pyrethrins was an efficient control of body lice, on rats when applied by atomization. Under the conditions of this experiment 5 cc. of the spray covered each animal effectively. Five per cent of the extract did not increase the efficiency of the spray. About 81% of the mites present upon the rats were destroyed by the spray. Spraying with any of the concentrations used did not injure the rats. Immersion in a 2% dilution destroyed all of the lice on the rats immersed. Immersion tended to injure the rats and is not to be recommended except when necessary. Five per cent dilution sprayed upon occupied cages controlled bedbugs without injury to the rats.

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THE PERFORMANCE OF CERTAIN INORGANIC INSECTICIDE DUSTS IN THE CONTROL OF CUCUMBER BEETLES

By HARRY F. DIETZ[1] and E. E. ZEISERT[2]

The purpose of this investigation was to test the reliability of the results obtained through several indirect methods of evaluating the insecticidal performance of treatments used in the control of free-moving, truck crop insects.

The indirect methods chosen are those generally employed in evaluating the insecticidal efficiency of dust and liquid insecticides used in the control of the cucumber beetles (*Diabrotica vittata* Fabr. and *D. duodecempunctata* Oliv.). Therefore, cucumbers were chosen as the test plant and these beetles as the test insect. To simplify the problem the test treatments were restricted to inorganic insecticide dusts.

In order to avoid misunderstanding, the term indirect methods of evaluating performance applies to such measurements as are not directly referable to counts of reduction in insect population or to the actual percentage of insects killed. Instead, reactions of the host plant, measured in length of vine growth; yield in weight of fruit; yield in total number of fruits produced; and freedom from bacterial wilt are used as criteria of insecticidal performance. Such use of these criteria is based on the assumption, tacit or otherwise, that reduction in population or percentage of kill is directly reflected in the plant reactions enumerated above. Of course treatments resulting in immediate, serious injury are excluded.

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If these several indirect ways of evaluating insecticidal efficiency are all closely correlated with reduction in insect population, it is natural to expect agreement in the results obtained from each. Our data do not support this premise.

EXPERIMENTAL TECHNIQUE.—Although it is axiomatic that the results obtained are inherent in the methods and in the measurements used, technique becomes an important factor when the real value is and remains an unknown.

It is an incontroversible fact that the number of uncontrolled and uncontrollable variables occurring in field experiments is large. The only possible escape from such dilemma is to control as many variables as possible and to measure or eliminate, insofar as possible, the effects of the rest. The best way to measure such uncontrollable variations as soil heterogeneity, differences in population in different parts of a planting, and similar factors is through restricted randomized replications.

REPLICATIONS.—Three hills of four cucumber plants each were used for each replication of a treatment and each treatment was replicated five times. Thus a total of sixty plants were used for each treatment. The distribution of the replications was made so that no treatment occurred more than once in the same row in either direction across the planting.

The planting was made on a level, fertile plot of soil with the hills spaced 10 x 12 feet. This wide spacing was employed because previous experience over three years had shown the necessity of wide spacing in order to avoid: (a) the interlacing of vines; (b) the drifting of the dust treatments to adjacent hills; (c) undue injury to the plants through cultivation; and (d) the packing of soil while applying treatments, taking measurements, and picking the fruits. At mid-picking season it was apparent that such spacing was not excessive.

TREATMENTS USED.—(1) Calcium arsenate—gypsum mixed in two ratios, 1 to 4 and 1 to 9 by weight. These were used as reference or standard treatments.

(2) Barium fluosilicate (Dutox) diluted in the ratio of 1 to 4 by weight with talc, flour, clay, high calcium and high magnesium lime, and a mixture of equal parts of talc and flour.

(3) Manganese arsenate compound (Manganar) mixed with gypsum and high magnesium lime in the ratio of 1 to 4; and with basic copper chloride and talc in a 1–1–3 ratio.

The gypsum, lime, and clay diluents were of 300 mesh size and very satisfactory for dusting purposes.

TIME AND METHOD OF APPLICATIONS.—All materials were applied as dusts and always on the same day. The first application was made soon after the plants appeared above the ground and their cotyledons expanded. A total of nine applications were made beginning June 21 (the first) and ending July 23 (the last). The time interval between applications was determined by the following factors: first, rainfall following previous application washing the dust from the plants; second, the observed abundance of insects in the planting; and third, the rapidity of growth. All plants were kept lightly and thoroughly covered with dust until fruiting began.

All applications were made with a Root Hand Duster. An exact record was kept of the amount (by weight) of dust used for each treatment.

The procedure in dusting was as follows: the first operation was to direct one or two strong puffs of dust into the center of each hill. This was done to secure thorough coverage of the bases of the plants, where the adult insects prefer to feed, particularly when the plants are young. The soil around the plants was likewise lightly and thoroughly covered. Subsequent puffs were directed to the undersides of the foliage and the final puffs to the upper surfaces. The number of puffs were kept as nearly equal as possible, taking into consideration differences in the size of the plants and the securing of a uniform visible coverage.

Since the weight of the material applied is known, we have some information relative to the influence on coverage of such physical properties of the diluent as density, suspensibility in air, cohesiveness and ease of flow. Color also is a factor as it influences the visibility of the dust on the plant.

Population Counts.—These counts were made just before and within twenty-four hours after any given dust application.

The small size and the agility of these insects which enable them to conceal themselves in the heavy foliage of well-grown cucumber plants obviously makes such counts by themselves inadequate. This is the primary reason why indirect methods of evaluation must be resorted to. Inaccurate as such counts admittedly are, they were taken for purposes of comparison with the indirect methods.

Vine or Growth Measurements.—Two such measurements were taken, the first following the sixth dust application; the second, just before picking time, and after all treatments had been discontinued.

Picking and Size of Fruit Picked.—Picking began on July 31 and was continued at three day intervals until September 15. All fruits two inches or over were removed at every picking and the number and weight of fruits recorded.

Results Obtained from Indirect Methods.—Table 1 shows the effects of these dust treatments on vine growth, number and weight of fruit, and incidence of bacterial wilt.

The following conclusions may be drawn from these data:

(1) In no case do the highest average vine growth, the largest number of fruits, the greatest weight of fruit, and the lowest incidence of bacterial wilt all occur in the same treatment.

(2) The incidence of wilt in any given treatment is obviously the most consistent measure of insecticidal efficiency and the average vine growth the least.

(3) Since cucumber beetles are the vectors of bacterial wilt, the incidence of this disease should and does coincide most closely with the observed abundance of insects found in the different treatments in the nine examinations made prior to each dusting. On four different inspections, of the nine made, no beetles were found in Treatments C, D, E, H, and K. The only dead insects found around the plants were found in Treatments C, D, and E.

TABLE 1. SHOWING THE RANKING OF VARIOUS INORGANIC INSECTICIDE DUSTS AS MEASURED BY INDIRECT METHODS OF EVALUATING PERFORMANCE

Treatment	Total wt. of dust ozs.	Wt. of fruit lbs.	Rank by wt.	Number of fruits	Rank by No. of fruits	Av. length of vines inches	Rank by av. vine length	Per cent of wilt present	Rank by wilt control	No. inspections free from beetles	Dead beetles found
A. Ca arsenate 1 / Gypsum 4	78	309	1	3231	1	33.9	6	6.6	3	0	——
H. Ba fluosilicate[1] 1 / Talc 2 / Flour 2	64	291	2	2905	2	28.75	9	1.6	2	4	——
K. Mn arsenate[2] 1 / Copper oxychloride 1 / Talc 3	64	289	3	2685	4	37.8	2	0.0	1	4	——
I. Mn arsenate 1 / Gypsum 4	76	266	4	2430	8	38.9	1	12.8	5	3	——
E. Ba fluosilicate 1 / Talc 4	55	260	5	2437	7	36.0	5	1.6	2	4	Yes
C. Ba fluosilicate 1 / Flour 4	84	252	6	2797	3	30.2	8	1.6	2	4	Yes
B. Ca arsenate 1 / Gypsum 9	75	247	7	2544	6	33.9	6	9.6	4	0	——
D. Ba fluosilicate 1 / Dawson Clay 4	61	245	8	2568	5	28.5	10	1.6	2	4	Yes
G. Ba fluosilicate 1 / High Mg. lime 4	67	209	9	1977	10	33.5	7	23.3	7	2	——
J. Mn arsenate 1 / High Mg. lime 4	66	203	10	1998	9	36.6	4	18.3	6	0	——
F. Ba fluosilicate 1 / High Ca lime 4	72	175	11	1609	11	37.5	3	33.3	8	0	——
Untreated Check	—	136	12	1125	12	[3]	—	50.0	9	0	——

[1]Ba fluosilicate refers to Dutox.
[2]Mn arsenate refers to the compound, Manganar.
[3]Too many plants being measured were lost from wilt, so no valid average was obtained.

(4) If the percentage wilt is taken as the best indirect measure of insecticidal efficiency, then it is clearly shown that the use of such chemically active diluents as high magnesium and high calcium lime cause a marked reduction in the efficiency of barium fluosilicate.

(5) High magnesium lime appears to cause less reduction in efficiency than high calcium lime.

(6) The technique of dusting used was satisfactory from the standpoint of uniformity of application as is shown by the following facts. Where the same diluent was used with different toxicants as gypsum with calcium arsenate and with manganese arsenate, the total quantity used in nine applications varied only three ounces. The same statement applies to the use of high magnesium lime with manganese arsenate and barium fluosilicate.

(7) Where different diluents are used with the same toxicant, the physical properties of the diluent such as density, suspensibility in air, cohesiveness, and ease of flow influence the quantity of material applied by the same method of application. Visibility of the dust on the plant also is a factor.

SUMMARY

(1) The growth and yield of plants are not necessarily a measure of insecticidal efficiency and may be influenced by factors quite distinct from freedom of insect attack.

(2) The results measured as weight of fruit and total number of fruit do not necessarily coincide and neither value by itself may be taken as a measure of insecticidal efficiency, unless supported by other evidence of a more direct nature.

(3) When indirect methods of evaluating insecticidal performance are used, the variations between them are sufficiently great so that no one measure can be used alone and several must be considered collectively.

(4) Direct measurements, no matter how inadequate they may seem, should be taken and the results compared with those obtained by indirect methods.

(5) When the results of several methods are considered collectively, a number of treatments may group themselves as among the best, any one of which would give satisfactory commercial control.

Friday afternoon session, December 28, 1934

PRESIDENT PHILLIPS: In the planning of the program this year it was decided to include some invitation papers to give an opportunity for a broader discussion of some of the problems in applied entomology which are attracting considerable attention, not only among entomologists but the public at large, during the past two or three years.

One of the outstanding problems, of course, has been the grasshopper problem.

Our first talk this afternoon will be by Mr. H. Gordon Crawford of Ottawa, Canada.

THE GRASSHOPPER OUTBREAK, 1931-1934, IN CANADA

By H. GORDON CRAWFORD, *Ottawa, Can.*

(Withdrawn from publication temporarily)

THE 1934 GRASSHOPPER-CONTROL CAMPAIGN

By J. R. PARKER, *Senior Entomologist, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture*

During the spring and summer of 1934 the United States Department of Agriculture, cooperating with 18 western States, conducted the most extensive and intensive grasshopper campaign ever attempted in the United States.

An unusual feature of the campaign was that the outbreak was accurately predicted and all details were planned in advance of the grasshopper season. The Congressional appropriation was made on the basis of surveys made during the previous year, bait was prepared and shipped

to areas where infestations were expected, and States were organized for control before grasshoppers hatched. This marked a decided advance over the usual method of planning and initiating control after grasshoppers have hatched and started to injure crops. Such delayed action results in severe crop damage before control measures can be applied, frenzied attempts to secure bait materials, and poorly organized campaigns which are only partially effective.

Detailed reports of control operations in particular States are within the province of the respective State leaders, but it seems desirable, and it is the purpose of this paper, to record in one article the more general features of the campaign.

OUTBREAK PREDICTED BY 1933 FALL EGG SURVEY.—Beginning in 1930 and continuing through 1933, grasshoppers, benefiting by favorable weather conditions, steadily increased over the northern Great Plains States. During this period sporadic attempts at control were made by individuals and counties, and in 1932 a most effective campaign was conducted in Minnesota, where the State appropriated $250,000 for control operations; but no unified effort was made for control over the entire region and as a result each year showed a larger area infested and greater crop losses.

Starting in 1931, the Bureau of Entomology and Plant Quarantine, in cooperation with State entomological agencies, conducted fall surveys of grasshopper conditions which accurately predicted grasshopper abundance the following spring. The results of the 1933 survey indicated that the worst grasshopper outbreak in the history of American agriculture could be expected in 1934 and that over 15,000,000 acres would need poisoning if crops were to be saved. The estimated needs of the various States for 1934 are shown in Table 1.

TABLE 1. ESTIMATED NEEDS FOR GRASSHOPPER CONTROL IN 1934 AS INDICATED BY THE 1933 FALL SURVEY

State	Number of acres needing poisoning	Tons of bait needed
North Dakota	5,439,680	27,198
Montana	3,613,058	18,065
South Dakota	2,567,396	12,837
Wyoming	841,600	4,208
Minnesota	333,400	1,667
Wisconsin*	320,000	1,600
Nebraska*	200,000	1,000
Idaho	120,000	600
All others*	1,600,000	8,000
Total	15,035,134	75,175

*Estimate not based on actual survey.

Due to limited funds, detailed surveys were made only in the States of Idaho, Minnesota, Montana, North Dakota, South Dakota, and Wyoming. It was known that grasshoppers were on the increase in many other Western States and a general estimate was made, based on the best information available, to cover unsurveyed States in which grasshopper control might be needed.

CONGRESSIONAL APPROPRIATION OBTAINED.—The prospects for grasshopper damage in 1934 were so alarming that a regional conference was called by The Greater North Dakota Association at Fargo on November 21 and 22, 1933, to determine what steps should be taken to combat grasshoppers in 1934. Three hundred persons attended the conference, including entomologists, official representatives from 7 States and 3 Canadian Provinces, farmers, and spokesmen for many business interests. After 2 days' deliberation, the executive committee selected by the general conference presented a report calling attention to the serious situations existing and the inability of the States and Counties to provide funds for the control of the grasshopper menace. Copies of this report were sent to the President and to the Secretary of Agriculture.

Recognizing the seriousness of the situation, the Department of Agriculture recommended to the President that funds be made available for the control of grasshoppers on a cooperative basis with the infested States. On February 1, 1934, the President transmitted to Congress a supplemental estimate of $2,354,893 for grasshopper control. This was included in the bill making appropriations for the Department of Agriculture, which was passed by Congress, and the money was made available on March 29, 1934. The Act covering this item provided that the Department of Agriculture should be responsible for general administration, supervision, and the purchase and transportation of poisoned bait, or materials for its manufacture, and that the cooperating States should be responsible for local distribution and utilization of such bait on privately owned land, including full labor costs. This Act further provided that in the discretion of the Secretary of Agriculture no part of the appropriation should be expended for grasshopper control in any State until such State had provided the necessary organization for the proper discharge of its responsibilities as outlined in the Act.

OUTLINE OF PROCEDURE.—On March 27, 1934, the Bureau of Entomology and Plant Quarantine issued an outline of procedure, approved by the Secretary and concurred in by the Director of Extension of the Department. This outline set forth the organization required of the participating States, called for the formation of a State grasshopper-control committee in each State as the organization responsible for applying for Federal aid in grasshopper control and for the organization and direction of the State activity, and outlined the manner in which application for bait should be made.

ORGANIZATION.—*Federal.* The Bureau of Entomology and Plant Quarantine was designated by the Secretary of Agriculture as the unit for carrying out the Federal phases of the Act. Lee Strong, Chief of the Bureau, placed the work under the immediate supervision of P. N. Annand, head of the Division of Cereal and Forage Insects. J. R. Parker, senior entomologist, directed and coordinated all work in the field. B. M. Gaddis, administrative assistant, was in charge of the field office at Minneapolis, Minn., and was responsible for the buying of materials, letting of mixing contracts, mill inspection, and the delivery of mixed bait or bait materials to the States.

Since control operations were to be conducted mainly through the

agricultural extension services of the various States, close contacts were maintained in Washington between the Bureau of Entomology and Plant Quarantine and the Extension Service of the U. S. Department of Agriculture.

State. The State grasshopper-control committees, in most cases, included the agricultural extension director, the experiment station director, the president of the agricultural college, and the State commissioner of agriculture, with the extension director as chairman. The duties of the committee were:

> (1) To receive requests for aid in grasshopper control from counties and to submit them to the Secretary of Agriculture with its recommendation;
> (2) to establish a State organization for the distribution and utilization of bait allocated to the State by the Secretary of Agriculture;
> (3) to designate a trained entomologist to act as State leader in grasshopper control;
> (4) to establish, in every county receiving Federal aid, a county leader (usually the county agricultural agent) to direct, under the general supervision of the State leader, necessary grasshopper control work within the county.

The State leaders were entomologists of the experiment station, extension entomologists, or entomologists of the State department of agriculture, depending on the organization in each State. Some States were divided into districts with assistant State leaders in charge of each district.

When State funds were inadequate to provide the personnel necessary to supervise control work, assistant State leaders and county leaders were employed by the Bureau of Entomology and Plant Quarantine but were placed under the direct supervision of the State leaders. Seventeen assistant State leaders and 20 county leaders, thus employed, were paid from Federal funds. Special assistance to Arizona, California, Oregon, and Utah was given by V. L. Wildermuth, C. C. Wilson, L. P. Rockwood, and G. I. Reeves, all of the permanent staff of the Bureau of Entomology and Plant Quarantine.

County. Before a county could receive Federal aid, it was necessary for a responsible officer of the county government to apply for aid through the State grasshopper-control committee. Such aid was given on condition that the county officials would recognize and support the county leader in grasshopper control, keep a record of all Federal bait received, and furnish satisfactory storage until such time as it was needed in the field.

Community and Township. Organization within the county was on either the township or community basis, depending on the local type of government. In order to insure that all land would be poisoned on a uniform basis and that no part of it would be left untreated, each township or community receiving Government bait was required to organize its own grasshopper-control committee. Such committees were headed by chairmen who acted as contact men between the farmers of their locality and the county leader in grasshopper control and included other members in charge of transportation, mixing stations, scouting crews, and bait-scattering crews.

ACTIVITIES PRELIMINARY TO POISONING OPERATIONS.—Each State desiring federal aid in grasshopper control organized a State grasshopper-control committee, appointed a State leader in grasshopper control, and submitted a petition to the Secretary of Agriculture stating its need for aid, an estimate of the quantity of bait needed, and a statement of the cooperation the State was prepared to give in conducting the campaign. If the petition was granted, steps were taken immediately to organize for grasshopper control on a State-wide basis. A representative of the Bureau of Entomology and Plant Quarantine met with the State committee and State leader and explained the control program. State leaders in turn called conferences and held training schools for county leaders. County leaders returned to their counties to conduct grasshopper meetings in every community and township where grasshoppers were expected in injurious numbers.

In North Dakota alone, 715 meetings were held with a total attendance of 38,000. In South Dakota 451 meetings were held with an attendance of 30,000. As a result of this intensive educational campaign conducted before grasshoppers had hatched, farmers, in most States, were fully instructed in control methods, and communities had chosen their leaders and were ready to wage intensive warfare against grasshoppers at the first appearance of the enemy.

BAIT PRODUCTION AND SHIPMENTS TO STATES.—Funds for the purchase of bait were not available until March 29. Due to the late date, farmers and agricultural leaders were apprehensive that the large quantities of materials needed could not be secured and mixed into bait before grasshoppers hatched, but favorable action by Congress and the President had been anticipated by the Department of Agriculture and everything possible in the way of preparation had been done except the actual purchase of supplies. As a result, the Department was able to establish a grasshopper-control office at Minneapolis, Minn., let contracts for bait materials and bait mixing, and start shipping prepared bait to the States in less than 3 weeks after the money became available. The unexpected early arrival of carloads of bait before grasshoppers hatched quieted all fears that the Government bait would not be delivered on time and had a marked effect in stimulating organization and educational work in the States and counties.

The first shipments of raw materials were made on April 4 and the first cars of bait were loaded on April 17. Production was continuous until July 9, during which time 70,481 tons or approximately 3,500 carloads of grasshopper bait were manufactured. In spite of the enormous tonnage involved and the many difficulties experienced in securing prompt delivery of raw materials to the mills, there was always mixed bait on hand for shipment whenever an order was received from a State leader, and no State control program was ever interrupted by delayed production. The outstanding work of B. M. Gaddis and his assistants in the grasshopper-control office at Minneapolis, who labored day and night to make all deliveries in the shortest possible time, has been highly commended by every State leader. It was only through the careful and well directed buying operations conducted by this office that it was

possible to manufacture the full amount of bait estimated, as purchases of the size required had a marked effect on the market price, particularly of bran.

Bait was manufactured under contracts with 8 mills located at the following points: Omaha, Neb. (3), Minneapolis, Minn. (2), Eagle Bend, Minn., Billings, Mont., and Livingston, Mont. Inspectors were stationed at each mill to insure proper arsenic content and mixing of materials. The formula used in preparing the bait was as follows:

Bran	50–60 percent.
Sawdust	20–30 percent.
Cane molasses	15 percent.
Crude arsenic (90 percent AS_2O_3)	5 percent.

This formula was selected after careful consideration of all factors involved. It could have been cheapened by omitting molasses and using a larger percentage of sawdust but it was considered necessary to use a bait that would be highly effective over the entire extensive territory infested and under varied climatic and crop conditions. The comparatively dry bait was shipped in burlap bags stenciled with the words: "Grasshopper Bait—POISON—Destroy This Sack." No water was added until the bait was used.

In some instances Federal aid was extended in the form of bait materials, $25 worth of raw materials being considered the equivalent of a ton of mixed bait. This was done particularly in States remote from mixing mills and in States where county mixing stations had been set up at local expense. Total shipments of mixed bait and bait materials to all cooperating States are shown in Table 2.

TABLE 2. QUANTITIES OF MIXED BAIT AND RAW MATERIALS FURNISHED TO COOPERATING STATES

	Mill mixed bait, tons	Raw materials shipped unmixed						Total bait, tons
		Bran, tons	Sawdust, tons	Molasses, gallons	Sodium arsenite, gallons	Crude arsenic, tons	Equivalent in mixed bait, tons	
North Dakota	26,996.19	125	3,275	——	86,000	—	1,308	28,294.19
Montana	19,109.40	——	——	——	——	—	——	19,109.40
South Dakota	12,830.95	——	——	——	——	—	——	12,830.95
Wyoming	4,320.00	——	——	——	12,290	—	135	4,455.00
Wisconsin	1,850.00	——	——	——	35,000	—	385	2,235.00
Colorado	——	1,800	——	——	18,000	—	2,070	2,070.00
Nebraska	2,082.64	——	——	——	——	—	——	2,082.64
Minnesota	1,981.72	——	——	9,600	——	20	65	2,046.72
Michigan	45.00	1,000	——	——	10,000	—	1,150	1,195.00
Idaho	705.00	——	——	——	——	—	——	705.00
California	——	600	——	——	3,000	—	645	645.00
New Mexico	40.00	460	——	——	4,600	—	529	569.00
Kansas	——	500	——	——	——	25	537.5	537.50
Oregon	——	347	——	——	5,000	—	402.5	402.50
Arizona	20.00	305	——	11,800	——	19	350.75	370.75
Nevada	——	290	——	——	1,475	—	311.75	311.75
Utah	300.00	——	——	——	——	—	——	300.00
Iowa	200.48	——	——	——	——	—	——	200.48
Totals	70,481.38	5,427	3,275	21,400	175,365	64	7,889.50	78,360.88

Total quantities of bait materials purchased by the Government during the campaign were as follows:

Material	Quantity	Average unit price
Wheat bran	42,933.1 tons	$18.86
Sawdust	22,022.4 tons	1.70
Molasses	10,608.3 tons	9.36
Crude arsenic	3,962.9 tons	34.65
Sodium arsenite	175,365.0 gallons	.265

CONTROL OPERATIONS AFTER HATCHING.—It was well that States were organized and that bait was available at an early date. Due to a remarkably mild winter and early spring over much of the Great Plains Area, grasshoppers started hatching nearly a month earlier than usual. Hatching began late in April and early in May and by May 10 was far enough advanced so that poisoning operations could be started in some States. Grasshoppers not only hatched as predicted in the States surveyed in the fall of 1933 but also appeared in destructive numbers in other Western States, and by June Government grasshopper bait or bait materials were being shipped to the 18 States listed in Table 2.

Excellent kills with the government bait were secured from the start and farmers fought valiantly to destroy the myriads of young grasshoppers which were invading their fields. Drought conditions made the situation more desperate. Cultivated crops in most areas were the only source of green food and grasshoppers hatching around the edges of cropped fields started to invade them within a few hours after emerging instead of remaining on their hatching grounds for a week or more as is their habit when green vegetation is abundant. Crops lacked moisture for rapid growth and did not have sufficient vegetation to delay grasshopper invasions. As a result, the young grasshoppers often advanced into the fields several rods each day instead of remaining concentrated along the margins as is the case where crops are making normal growth. Hatching continued on warm days over a period of several weeks with new hordes of grasshoppers invading crops after each hatch. Under such conditions, control could only be obtained by repeated applications of bait around the field margins and for several rods into the fields.

In spite of these difficulties, crop losses were held at a minimum and there was no sign of letting up until early in July. By that time it became apparent over much of the area that the severe drought had injured crops to the extent that few of them would be worth harvesting. With no crops to save, some farmers gave up but even then the majority showed surprising determination and continued the campaign in order to prevent an outbreak the following year. In all areas where crops were worth harvesting, the campaign was surprisingly effective. In spite of adverse conditions for poisoning and the presence of more grasshoppers at hatching time than in any previous outbreak there were no extensive crop losses in any of the States.

For 3 years previously, leading newspapers in the Great Plains States during June and July had featured front-page stories of grasshopper destruction. During 1934, a first-class clipping service failed to gather a single feature story of grasshopper damage.

VALUE OF CROPS SAVED.—Throughout north-central Montana, which suffered extensive crop losses from grasshoppers in 1933 and which was the most heavily infested area in the Great Plains region in the spring of 1934, weather conditions were favorable and the best grain crop in years was produced with only slight injury by grasshoppers. It is quite generally agreed by farmers in this area that vegetation would have been entirely devastated by grasshoppers if control measures had not been employed. Good crops were also grown in the Red River Valley in North

Dakota and Minnesota where lack of control measures would have resulted in total destruction of crops on hundreds of farms. Thousands of acres of crops in Western States saved from the drought by irrigation were also protected from grasshoppers by poisoning operations. No accurate estimate of the value of crops saved from destruction by grasshoppers can be made but control-campaign leaders from 18 States in conference at Denver, Colo., on August 31, 1934, stated that it would exceed $50,000,000. If drought conditions had not destroyed crops after they had been saved from grasshoppers, the saving would have been several times this figure.

ACCURACY OF ESTIMATES.—In the fall of 1933, it was estimated that the 8 States of Idaho, Montana, Minnesota, Nebraska, North Dakota, South Dakota, Wisconsin, and Wyoming would need 67,175 tons of grasshopper bait in 1934. A general estimate of 8,000 tons was also made for all other States which might need Federal aid.

After the 1934 campaign was closed, a check was made through all State leaders to determine the quantity of bait actually used in each State, including bait supplied by the Government and with local funds. It was found that in the 8 States mentioned above 68,137 tons had been used and in the 10 other States approximately 6,500 tons. The estimate for the 8 states was, therefore, within 1.4 per cent of being correct and within 18.7 per cent for the miscellaneous group of States. The total amount of bait estimated as needed for all States was 75,175 tons and 74,637 tons were actually used, a difference of only 538 tons which is less than 1 per cent.

The accuracy of the estimates illustrates the value of the grasshopper-survey technique and methods of making estimates which have been worked out by the Bureau of Entomology and Plant Quarantine Laboratory at Bozeman, Mont. Without a survey and fairly accurate estimates on cost of control, there would have been no reliable basis for determining the amount of the Congressional appropriation needed nor could as much of the work been conducted in advance of the hatching period. It is believed that surveys of this nature deserve a permanent place in grasshopper control.

DISCUSSION OF METHODS USED.—The campaign has again demonstrated the value of the poisoned-bran-mash method of control and shows that when properly organized it can be as successful over an entire region as it has been in the past in States and counties. There was nothing new in the methods employed except in the scope of territory covered and in planning all phases of the campaign before grasshoppers had hatched. The possibility of complete control of grasshoppers on a county-wide basis by the use of poisoned-bran mash was first demonstrated in Kansas in 1913, (*3*), (*4*). During the period from 1921 to 1924, 30 counties in Montana spent nearly half a million dollars of their own money in poisoning 2 million acres and saved crops valued at $5,390,000. During that time a very effective method of organization for grasshopper control was worked out and published by the Montana Experiment Station (*2*). It stressed in particular community action to insure complete and early treatment of all infested land.

In the fall of 1931 following the severe outbreak of that year, a conference of entomologists was held at Sioux City, Iowa, to discuss plans for combating the extensive outbreak that was expected in 1932. At that time representatives of the Bureau of Entomology and Plant Quarantine presented a plan based on the methods used in Montana but broadened to include all grasshopper-infested States and to unite State and Federal entomological agencies in cooperative action. During the following winter when it seemed likely that Congress would appropriate money for grasshopper control, this plan was presented in writing to entomologists of grasshopper-infested States and after some revision to meet the needs of individual States was agreed upon as satisfactory to all concerned. The Congressional appropriation unfortunately did not materialize and Minnesota was the only State that provided the necessary funds to put the State and county features of the plan into effect in 1932. The highly successful campaign conducted by A. G. Ruggles and his assistant T. L. Aamodt is a matter of record (*1*). The fact that Minnesota was able to save its crops during the worst grasshopper outbreak in 50 years was a most important factor in creating confidence in grasshopper-control methods and made it much easier to induce farmers in nearby States to fight grasshoppers in 1934. When it became apparent that a Congressional appropriation would be available for 1934, the same plan in simplified form was again presented to the State entomologists and was adopted for use in the 1934 campaign. Many workers in the Bureau of Entomology and Plant Quarantine, various States and Canadian Provinces have contributed to the gradual development of the poisoned-bran-mash method of control to its present state of effectiveness.

Cooperation of Many Interests Responsible for Success.—Much of the credit for the success of the campaign is due to the spirit of cooperation and whole-hearted enthusiasm for the work displayed by all persons and organizations connected with it. Railroads granted reduced rates and other concessions which enabled the Government to save several hundred thousand dollars which was used in the purchase of materials instead of in freight payments. Many of the railroad agricultural departments furnished men with grasshopper-control experience to aid the State extension services in educational work. Elevator companies provided free storage of bait at numerous rural points and bran producers frequently sold to the government when their regular trade was demanding more than could be supplied. The Northwest Crop Improvement Association and the Greater North Dakota Association gave the campaign their full support and were particularly successful in obtaining the cooperation of business interests. Service clubs gave grasshopper control a prominent place in their programs and emphasized the fact that curbing the grasshopper menace was almost as important to business and professional interests in towns and cities as it was to farmers in adjacent agricultural districts. Federal, State and county leaders in grasshopper control worked regardless of hours or holidays. Most important of all was the determination and fighting spirit of the farmers themselves. Over and over again during the campaign farmers remarked:

"The Government has given us this bait and it's up to us to make the best possible use of it." Somewhat doubting its effectiveness at the start, they were willing to give it a fair trial. Then convinced that it did the work, poisoning was continued until grasshoppers were controlled or drought conditions had eliminated all hope of a crop. Even under the latter conditions, thousands of farmers continued to poison in order that there might be fewer grasshoppers to lay eggs for next year. As a result crop losses for the current year were largely prevented, grasshopper populations were reduced to the lowest point of the last 4 years, and farmers and business men throughout the grasshopper-infested States were convinced that grasshopper control is effective and economical.

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...Mr. Arthur Gibson took the chair...

CHAIRMAN GIBSON: Are there any questions anyone would like to ask Dr. Parker or the preceding speaker?

MR. W. P. FLINT: I would like to ask Dr. Parker if he has any evidence of the killing of birds or animals anywhere in the area?

DR. J. R. PARKER: We asked all state leaders to keep a record of all such cases. We had a good many animals killed, but always due to carelessness. There was not one proven case of birds, live stock or animals being killed by grasshopper bait when it was properly scattered.

MR. DUGITON: I would like to ask if that statement holds for the dead grasshoppers. Suppose anything happens there where the animals are feeding.

DR. PARKER: Yes, that holds true for the dead grasshopper. We have had a good many cases of turkeys dying from gorging on dead grasshoppers and live grasshoppers, too, but that is because of the physiological conditions, becoming crop-bound.

THE MOSQUITO CONTROL WORK OF TODAY

By F. C. BISHOPP, *Washington, D. C.*

(Paper not received in time for publication.)

THE EUROPEAN CORN BORER: PAST, PRESENT AND FUTURE

By J. J. DAVIS,[1] *Purdue University Agricultural Experiment Station*

In the handling of any problem it is desirable occasionally to completely survey the work of the past, analyze its present status and attempt to predict the future of the problem and organize the program of study to be recommended for the years to come. Seventeen years have passed since the European corn borer was first discovered in North America and ten years since it first caused commercial damage to corn and was definitely recognized as a potential corn pest. During this period the insect has demonstrated beyond the question of a doubt its ability to cause enormous losses under certain conditions and has spread over a large area of Canada and into the states of Massachusetts (1917)[2], New York (1919), New Hampshire (1920 or 1921), Maine (1920 or 1921), Rhode Island (1920 or 1921), Pennsylvania (1921), Ohio (1921), Michigan (1921), Vermont (1923), Connecticut (1923), New Jersey (1926), West Virginia (1926), Indiana (1926), Kentucky (1930), Virginia (1931), Wisconsin (1931), Maryland (1932), Delaware (1934), covering an area of 66,100 square miles in Canada and 246,721 square miles in the United States. In spite of this enormous spread it is a fact that commercial loss has resulted in only relatively small areas, a fact which leaves doubt in the minds of many individuals as to the future significance of the corn borer. This is a reasonable doubt which can be clarified only with a full understanding and proper analyzation of the evidence. Studies of greater or less extent have been carried on by Dominion, Federal, Provincial and State investigators. The research activities have seen agronomists, plant breeders, agricultural engineers, animal husbandmen, and agricultural economists closely cooperating with entomologists in a very effective way. Furthermore, the results of several of the investigations have yielded information, aside from corn borer control, which has a large and immediate application in the betterment of agricultural practices.

RESULTS OF RESEARCH TO DATE.—Obviously the first consideration in any problem in economic entomology is a knowledge and understanding of the life history and habits under varying ecological conditions and the structure of the insect in question, since the controls are all based on our knowledge of these points. In the case of insects which are of great economic significance or potentiality, it is highly important that studies on the life history and habits be intensive because some appearingly minor point may be the vital information leading to a practical control. Inasmuch as the European corn borer has been considered a potentially serious corn pest ever since it demonstrated its actual destructiveness in Canada, much attention has been given to all details of its bionomics. The results of these studies, as already inferred, have

[1]The writer is obligated to corn borer investigators in Canada and the United States, and especially to W. A. Baker, R. M. Merrill and G. A. Ficht, for many facts included herein and for confirmation of questionable points.

[2]Dates following states refer to dates of first record.

been the basis of every control development. A résumé of the preventive and control measures thus far promoted, which follow, emphasize the significance of an initial understanding of the insect bionomics and their use in the development of controls.

Mechanical Controls. The fact that the overwintering borers are in corn stalks and stubble, emphasized the need of disposing of these crop residues and is the basis of nearly all of the developments in the field of agricultural engineering. This has resulted in the designing of new machinery, and especially new attachments for machinery already on the farms. It has also been the incentive to provide better methods of using the present implements for disposing of crop remnants than have been common practice in the past. Thus, the engineering research has developed, improved or adapted for use in corn borer control such tools as plows and plow attachments, low cutting devices for binders, sled cutters, rakes, corn huskers and shredders, cutting boxes, low-cutting hand knives and hoes, stubble beaters, burners and other special combinations of machines designed primarily for simplifying control by harvesting the corn and disposing of the fodder with one operation.

In view of the great number and variety of methods which have been developed, growers have considerable choice in selecting the means by which they may handle the corn crop and dispose of its remnants. Among these developments are some which will be of unlimited value and use in fields other than corn borer control and a few of these may be mentioned specifically.

The problem of complete coverage of infested material so as to leave no shelter for borers on the soil surface has resulted in the final development of trash shields and self aligning disc jointers for plows which will permit complete coverage of such bulky plant residues as standing corn stalks and sweet clover. This one development will prove invaluable in regions where large amounts of plant residues must be plowed under. The value of this practice alone may amply repay for all monies expended for corn borer research.

Since the borers migrate to the lower and moister portions of the stalks towards fall, the cutting of corn at the usual height left many borers in the stubble. Thus, low cutting attachments for corn binders, inexpensive sled corn harvesters which cut the corn at the ground surface, and low cutting hand hoes for use in harvesting small acreages were developed. This low-cutting operation leaves comparatively few borers in the field and if the corn is then ensiled or properly shredded, all borers contained in the fodder are disposed of. Under most conditions the field can then be planted to winter wheat without further attention, which, of course, would not be the case if wheat is planted in standing corn or stubble cut a foot above the ground. Aside from their use in corn borer control these low cutting devices will allow for an increased production of silage per acre of corn.

Field burners have been developed for the disposal of corn stalks in the field but due to the high cost of burning, this method of stalk disposal will probably only be used where a quick, thorough clean-up of an isolated infestation is required. However, these burners have found a

possible practical use in orchard burning to destroy overwintering codling moths, apple curculios and scab spores.

The agricultural engineers have made excellent progress in providing equipment necessary to adequately dispose of plant residues in which the borer passes the winter. The further perfection of such equipment and methods is desirable and there is need for the development of machinery for applying insecticides which have proven partially effective in corn borer control and which may prove practical in protecting sweet corn canners against huge losses from corn borer and corn earworm attacks.

Agronomic Practices. Here again we find that an understanding of the life cycle and habits of the insect in question is essential to the development of agronomic controls. The fact that corn borer populations can be correlated directly or indirectly with such agronomic factors as soil fertility and fertilization, date of planting, rate of planting and plant distribution, crop rotation and corn acreage and substitute crops makes the agronomic investigations in connection with corn borer control of the utmost value. Working jointly, agronomists and entomologists have already made important contributions to our knowledge of the behavior of the corn borer and to measures which will greatly assist in control. Some of the more important ones might be mentioned here.

The research work of many agencies has shown that the growth and vigor of corn as expressed by its height at the time of oviposition governs to a large extent the number of eggs that it will receive. Also, it was determined that moths emerge and lay eggs during late June and early July. With these observations as a basis, field studies on the effect of planting date on corn borer populations have been made in many states and provinces which show that corn planted after certain dates is free or comparatively free from borer infestation. All of these studies lead us to believe that delayed planting will be a valuable practice to aid in corn borer control, especially as an emergency control in time of dire need. In each region where the corn borer is likely to appear, it would be a distinct advantage to conduct planting date studies in advance with special reference to high yielding varieties with a growing period suitable to the required sowing date.

Soil fertility and fertilization have been shown to have a marked effect on corn borer populations, largely because of their effect on the vigor and growth of corn. However, fertilizer research in connection with the corn borer problem has probably found its greatest usefulness in hastening the maturity of late planted corn and thus improving yield and quality in delayed plantings. The impetus given these studies as a direct result of the presence of the borer has added greatly to the general knowledge concerning the effects of fertilizer of various compositions on the yield and quality of corn. Also, numerous studies on proper fertilizer placement in relation to the seed have brought out points of economic value to corn growing in general.

The rate of corn planting, whether hilled or drilled has a definite agronomic aspect as it relates to yield and an entomological relation as to corn borer populations. From these studies we conclude that the eggs

are not deposited on the plants directly on the basis of plant or unit area but that such distribution is influenced more by unit area than by plant unit. The indication is that somewhat thicker stands than are ordinarily grown would decrease the number of borers per plant unit to a point below that which now exists in the infested areas and reduce corn borer damage. These researches also tend to show that thicker and more uniform stands might increase corn yields, in most cases, regardless of the presence of the borer.

Crop rotation studies in relation to the corn borer problem largely evolve around the subject of fertility, which has already been mentioned, and the subject of rotations which will permit the plowing of fields following corn as a finishing operation to corn lands by which the necessity of discing up stalks or stubble for the succeeding crop may be avoided. Several years of study on this subject have given useful information which should enable the making of definite recommendations in infested areas should any change in rotations become necessary because of the presence of the borer. Many agencies are already prepared to recommend various substitute crops in order to provide for such changes as may be necessary in cropping practices and rotations or in instances where it is physically impossible to dispose of the crop residues of the large acreages of corn now being grown.

These problems and others of a related nature have been the main corn borer problems with which the agronomists have been concerned and the progress to date offers many results of economic value to the future of the corn borer work as well as to other related corn growing problems.

Corn Breeding. There is probably no phase of corn borer research which offers more opportunity at the present time for producing effective assistance in borer control than that of the selection or production of resistant and tolerant strains of corn for use in the infested areas. It was early recognized by several workers that early strains of corn were less resistant to attack by the borer than late strains and that the length of the required growing period of a variety governed to a large extent its resistance to attack as indicated by the comparative rate of survival and larval establishment in early and late strains. Since this early work, many agencies have discovered that most strains of corn vary somewhat in their comparative resistance and tolerance. The result is that much progress has been made in very recent years on this problem by plant breeders and entomologists and results of marked value will undoubtedly be available in the near future.

Farm Management. Farm management problems relating to the changes in ordinary farm practices which will be necessary to improved methods of corn borer control in the event of the occurrence of severe infestations have been studied by investigators in this field of research. Of particular interest, are the determinations of the relative costs of putting into operation the recommended methods of control. The relative cost of disposing of crop residues by different methods, of using substitute crops for a part of the corn acreage, and the cost of effecting changes in some of the crop rotations now in use in order to allow for

the disposal of the residues as a finishing operation in corn borer control, have been some of the important farm management problems considered. The increased use of farm animals to dispose of excess corn fodder on some farms, the increased use of silage for disposing of crop remnants and the planning of the farm work to meet the altered farm practices have been studied. Such problems are of a nature which vary on each individual farm and such contributions as have been made by the farm management workers will greatly assist the individual growers in solving the questions of modified farm methods and operations and in helping them plan to live with the corn borer. In this connection it might be further noted that with the methods now known, effective control of the corn borer requires that community sentiment be aroused so that the efforts of individual farmers who incur extra expenses for control are not nullified by the failure of other farmers to do their share. Although it may not be profitable for individual farmers to incur any considerable expense in controlling the corn borer either by changed rotations or changed crop practices until actual corn borer damage has aroused this community sentiment, it is possible in many cases to prepare for the corn borer by making changes which do not reduce incomes. It is also desirable that changes which involve extra costs be planned ahead of time so that farmers are prepared to adopt them without undue delay when the necessity arises.[3]

Insecticides. Much work has been done by several agencies in the development of insecticides and insecticidal methods for reducing infestation and damage from the borer to corn, especially sweet corn, and in the two-generation area also to other economic plants which chronically become infested. A large number of insecticides have been tested and while most of them have been unsatisfactory from some point of view, a few promising ones have been isolated. The studies of insecticides and methods to date give reasonable assurance of the practicableness of insecticide control for sweet corn and certain other crops, and it is not unlikely that the principles of control for corn borer may be the basis for an insecticide control for the corn earworm, which is recognized as the cause of great losses to sweet corn and not infrequently to field corn. A practical insecticide control for either corn borer or earworm or both would be of inestimable value to growers of market and canning corn.

Utilization of Parasites. Soon after the corn borer was discovered in the United States, studies were inaugurated by the Federal Government to rear and import from Europe, parasites of the borer. Later similar importations were made from Japan. From that time (1919) to the present, this has been a major feature of the Federal corn borer investigations. Some 20 species of parasites have been studied and their establishment attempted. Of these, at least two, a hymenopteron (*Inareolata punctoria* Roman) and a dipteron (*Lydela stabulans*, var, *grisescens* Meig.[4]), show establishment and definite control possibilities. It should

[3]Bul. Purdue University Agricultural Experiment Station, No. 389, Mar. 1934, p. 4.

[4]Earlier references to this species used the name *Masicera senilis.*

be kept in mind that the success of parasite introduction is dependent on a continuity of work over a long period of time, and that the introductions should keep pace with the spread of the insect. The establishment of useful parasites will in all probability be a permanent agency in natural control. It is significant that the weather conditions in recent years, which have been unfavorable to the borer, apparently have been less so to the parasites.

In this connection it might be noted that the feeding of ladybird beetles on borer eggs has been conspicuous, in some areas. Also, in many regions the downy woodpecker has riddled cornstalks during the winter months in its search for borers. While the activity of this bird shows up in a striking way in lightly infested areas, its effect on the corn borer population is scarcely measurable in areas of heavy infestation.

Quarantine. While it has been the universal opinion of entomologists that the corn borer could not be exterminated, quarantines have been maintained to restrict its spread. In other words, the quarantines were not intended as an aid in the extermination of the corn borer but rather to retard the rate of spread and to prevent long distance carriage and establishment until controls could be developed. That the quarantines are fulfilling their purpose is evident from the fact that all spread of the borer has been a natural one, which might be expected, and the borer has not become established at points distant from the area infested, except where rivers have been responsible for the carriage of infested stalks. Except for quarantines we would probably be faced with a serious situation in many localities before controls were developed and their application established. With the quarantine in operation, research has had time to provide practical controls and farmers are gradually becoming acquainted with the practices which they must apply as the insect becomes increasingly important in their locality.

Clean-up. Clean-up and destruction of all crop residues harboring the borer has been demonstrated to be the most practical measure yet developed for general corn borer control. Its value has been amply established in Ontario, Canada and the possibility of its utilization in the United States was evident during the progress of the $10,000,000.00 clean-up campaign. Much has been said of this ten million dollar appropriation made by Congress in 1926 to determine the possibilities of legal enforcement of quarantine and clean-up methods. The instigation and purposes of this project are still confused in the minds of many and it is well to quote from a paper read at the corn borer conference in Washington, D. C., on March 24, 1932, as follows:

> "At the request and with the approval of agriculturists and state agricultural officials in affected states, Congress in the summer of 1926 appropriated $10,000,000 to control the corn borer. The greater proportion of this large sum was returned to the farmers as payment for thorough clean-up of their premises in infested territory. At the inception of this intensive campaign it was realized that extermination of the borer could not be expected. One of the greatest benefits derived from this immense expenditure was the educating

of the farmers of America to the fact that they have it in their power to prevent a further increase in the number of borers and to materially lessen the intensity of infestation in whole sections of country. It was proved entirely feasible to destroy so many borers that their natural increase is negligible and the possibility of obtaining a satisfactory stand of corn assured. Despite this unparalleled control campaign with its intensive educational features, experience in the years subsequent has shown the necessity for constantly prodding those whose crops are affected to prevent recurrence of the disastrous Canadian situation."

DISTRIBUTION AND ECONOMIC IMPORTANCE.—As stated, the European corn borer is now established in 18 states and over a large area in Canada. It has been noted that the area of commercial damage is relatively small in comparison to the total infested area. This has led many to question the fear of the corn borer, so often expressed. Whether or not the corn borer will become a serious problem in this or that region cannot yet be predicted. The expectancy curve is dependent on a great variety of biotic and physical factors, many of which have been pointed out by Babcock, Huber, Transeau and their associates. Perhaps the outstanding reasons for fearing the corn borer are the demonstrations of its ability to destroy corn in Ontario, Canada, St. Claire County, Mich., in Connecticut and elsewhere; its ability to reproduce to enormous numbers, given the proper environmental conditions; and the huge value of the corn crop.

Demonstrations of the destructiveness of the borer are worth considering. The seriousness of the borer in Ontario, Canada, bordering Lake Erie was thoroughly demonstrated in 1925 and 1926 and needs no comment. Here the drastic enforcement of the Corn Borer Act, requiring the adoption of clean-up practices, has been accompanied by a reduction of borers and a return to the normal corn acreage. Since 1928 very few fields of corn anywhere in the province have been ruined or even very seriously injured, and this can be largely attributed to clean-up practices. It is believed that unless and until natural controls become controlling factors, protection of the corn crops of Ontario will be dependent on the continuous and regular application of artificial controls.

In New York moderate loss to sweet corn has occurred where the single-brooded strain occurs, bordering Lake Ontario. Serious damage is common on the eastern portion of Long Island where the two-brooded strain is established. In fact, as a result of the activities of this insect and the corn earworm, it is becoming unprofitable to grow corn in some districts in this area.

Some definite figures are available from Connecticut where the two-brooded strain, especially in the Connecticut River Valley, has been an important pest for the past two years. A large part of the losses occur on sweet corn, although considerable damage has been noticed on field and silage corn, as well as to tomatoes, peppers, string beans, rhubarb, beets and squash. According to the survey figures of J. P. Johnson for 1934, the first generation caused a loss of $48.60 per acre on sweet corn;

mid-season corn, maturing during August escaped serious damage; and late corn showed an average loss of $23.60. It is estimated that the annual damage caused by the corn borer on sweet corn in Connecticut is at least $100,000.00. Damage to field and silage corn is estimated to be at least 10 per cent. It should be added that this damage has occurred in spite of clean-up measures. It is believed that the failure to reduce the corn borer population from season to season in the heavily infested areas has been due to lack of complete disposal of corn debris by many individual farmers.

In Massachusetts the one and two brooded strains now overlap in the Connecticut River Valley. Severe damage has occurred in eastern Massachusetts for a number of years, and in the Connecticut Valley region it is apparently in about the same intensity as in Connecticut.

There is definite evidence that the corn borer will find conditions favorable along the Atlantic Coast from New Jersey south, and that we can anticipate serious trouble in these regions.

We might go on and point out other regions where the corn borer has been a factor of considerable importance.

Since it is true that the corn borer under certain conditions, which we are considering as favorable, can increase to enormous numbers in a few years if unchecked, why have they not become a serious problem in Northeastern Indiana, for example, where the insect has been known to occur for the past eight years. Undoubtedly the biotic and physical factors have been responsible for preventing rapid increase in this region. Of the biotic factors, perhaps parasitic and predacious enemies have played little part. However, it is a fact that farmers are realizing the value of clean-up practices as a good farm practice, regardless of the borer, and undoubtedly clean plowing, low cutting and such measures must have some effect on the borer population. Of the physical factors, perhaps climatic conditions during egg-laying and incubation have been predominant, although there are many other physical factors that probably entered in. For example, during the past five years, 1931 was favorable to the borer, 1932 not entirely unfavorable, while 1930, 1933 and 1934 were definitely unfavorable. In spite of these conditions in Indiana, the borer has shown a measurable increase in density of population except in 1930 and 1934, a situation which reveals a potential reproductive capacity of significance if and when we have several years of normal and favorable conditions. The season of 1934 definitely set back the borer several years, at least in the drought areas of the central west. The hot, dry winds early in the season resulted in curling of the corn leaves and peeling off of the egg masses, while the continuous dry weather was very destructive to the few that finally hatched.

DEBIT AND CREDIT.—The question frequently asked is whether the European corn borer is as great a pest or is likely to become a pest of as great importance as originally predicted, and have we been justified in the expenditures of large sums of public money? Has the expenditure of these public funds produced justifiable results? Are we justified in asking for funds for a continuation of research and certain phases of quarantine, and if so what should be the trend of this research? These are

momentous questions and possibly no one can answer them all with exactness or at least to the satisfaction of everyone. And yet a clear understanding of the problem leads us to feel that reasonably direct and correct answers are available for all of them.

Those who originally predicted that this insect would become abundant in all of the "corn belt" and other corn growing areas and "wipe out" the corn industry were undoubtedly mistaken. Those who believed that it would become a future serious corn problem in important corn growing regions probably were not mistaken. As has been shown, the borer is already a serious problem in areas of greater or less extent in a number of localities, and while the biotic and physical factors will naturally play the significant role in natural or automatic control in many corn sections, even then we have reason to anticipate occasional outbreaks as we now have occasional outbreaks of chinch bugs, army worms, grasshoppers and the like.

A study of all facts leads us to unhesitatingly conclude that the large sums of money expended for corn borer research have been fully justified. Should the corn borer be of no further economic importance the expenditures to date would be justified, because from the very beginning this insect has been recognized as a potential destroyer of the nation's most valuable crop and the amount expended was no more than any good business man would pay for insurance on equally valuable property to repay for any losses that might be caused by fire or other hazard. The many valuable results of the research effort, made possible by federal and state funds in the United States and dominion and provincial funds in Canada, have been briefly enumerated. These accomplishments have not only given us means of handling the corn borer problem where it becomes destructively abundant, but also have an additional great value to the agricultural industry by providing equipment and methods for the betterment of agriculture, regardless of the corn borer.

There is another result that may be indirectly attributed to the European corn borer studies which I would like to refer to because it has far-reaching possibilities. In the early days of Entomology,—and perhaps every other technical subject, each entomologist was to a large extent a worker unto himself. During the past decade we have seen jealousies and professional secrecies, which previously existed between individuals, almost wiped out and at the present time we find complete cooperation between federal and state entomologists and between those of adjoining states, with wholesome effect and a multiplication of results. Although for a number of years workers have recognized the relation of entomology, agronomy, plant breeding, agricultural engineering, horticulture and other agricultural industries, the interdependence of these various agricultural activities and the great value that would result from a close cooperation was not generally recognized by practice until recent years. The present cooperative and interdependent spirit now existing between all agricultural agencies can perhaps be traced directly to the cooperative work found to be so essential in the solving of the corn borer problem. If

it has done nothing else, this result alone is of sufficient value to justify the expenditures for corn borer research.

WORK OF THE FUTURE: FEDERAL AND STATE RESPONSIBILITY.—We now must decide whether or not the work of the past, the present situation and the predictions for the future, justify continuation of corn borer investigations and continued support by federal and state agencies in the United States and dominion and provincial agencies in Canada. The European corn borer is a potential menace to corn and other crops in the United States and Canada, just as surely as fire and wind are potential menaces to one's home. Many sections of the United States have never been visited by a tornado and yet it is doubtful if any county is without more or less tornado insurance. The story is very aptly told in the last three sentences of the summary of the Ohio monograph on The European Corn Borer and Its Environment[5] as follows: "There is as yet insufficient evidence to warrant a prediction as to the exact future significance of the corn borer in Ohio agriculture. However, there is justification for the statement that the insect will never be of equal economic importance in all parts of the State and that corn will continue to be the major crop even though later planting be necessary in the most favorable corn borer areas. This prediction presupposes of course, that the research now in progress will be carried to its ultimate conclusion." Much progress has been accomplished to date and commercial controls are already available for many localities. But certain promising phases of the work are not yet complete and we must adapt practices applicable in one locality to new localities as the borer spreads. We must not drop scouting and survey work entirely for it fulfills the service of keeping us advised of the spread and relative increase in different localities and the factors responsible. And last but by no means least, although probably most neglected, is the comprehensive ecological study, such as was so admirably started in Ohio by Huber, Neiswander, Salter and others. Such studies will doubtless materially aid in improving our controls as well as aid us in determining the likely areas of chronic infestation. We therefore conclude that corn borer investigations should be continued, not with lavish funds, but sufficient to carry out the most essential phases which are enumerated in the report of the committee on Corn Borer Research, already reported to this Association.

THE CHINCH BUG

By W. P. FLINT, *Chief Entomologist, State Natural History Survey and Ill. Agr. Exp. Station, Urbana, Ill.*

The present status of the chinch bug as the most destructive corn insect in the United States is the direct result of farming for chinch bug production. The chinch bug is one of the most outstanding examples of the benefit derived by an insect from our present system of agriculture in the middlewestern states. It has probably caused more damage over the last one-hundred year period than any other insect with the possible

[5]Bul. Ohio Agr. Exp. Sta. No. 429, Dec. 1928 p. 191.

exception of the grasshopper and the cotton boll weevil. That this position as to destructiveness is of no recent development is appreciated by a review of any of the earlier publications dealing with the chinch bug.

The following quotation from an article by Dr. S. A. Forbes[1], written 52 years ago, illustrates the importance of the insect at that time: (1880)

> "It requires neither figures nor rhetoric to enforce the importance to agriculture of this especially destructive and unmanageable pest of the grain fields. The fact that it is the most dangerous insect foe with which they have to deal—that it taxes them more heavily than all other enemies combined, is burnt into the conviction of thousands of farmers by repeated heavy losses and bitter disappointment.
>
> "Not the least serious feature of the situation is, the apparently uncontrollable character of its injuries. Notwithstanding the intelligent thought and energy which have been concentrated for more than a generation on this insect, it has continued to thrive—as little affected by any action which human ingenuity has brought to bear upon it as is the course of the weather or the orbit of the earth. Its coming and going, its abundance and its scarcity, seem regulated by causes, thus far, beyond our reach."

The chinch bug has been a serious pest of midwest agriculture since the time when the prairies were first broken up into farms. Probably the first report of its damage is in Fitch's second report of "The Insects of New York State," page 279. He states that in 1785 the wheat fields of North Carolina were so overrun by chinch bugs as to threaten total destruction of the grain. There are several other reports of its damage in 1700.

It was apparently an important pest of Illinois agriculture from almost the start of farming in that state. It is reported to have damaged a crop of oats sown on a farm near Olney, in southern Illinois, in 1823. This was the second year that this land had been farmed, the land having been taken up from the Government in 1821.[2] It is reported to have been very abundant on the prairies of northern Illinois at several times before any of the land had been broken or any farming carried on within a number of miles of the point where the insect was observed. Here, according to reports, it was feeding on the prairie grasses, especially on the tender shoots of *Andropogon*.

According to a theory of F. M. Webster's[3] the insect was probably of Central American origin. He established a theory of its migration northward through central America. The migration then divided into three lines, one of which followed the eastern coast up to the Maritime provinces of Canada. The second followed the Pacific coast but was not as strong a movement as that along the east coast. The third, according to Webster's theory, followed up the Mississippi Valley and bugs from this

[1]Twelfth Report Illinois State Entomologist, page 32.
[2]S. A. Forbes, "Insect Life", February 1889.
[3]"The Chinch Bug", Bulletin 69, Bureau of Entomology, 1907.

migration apparently encountered conditions that were very favorable to them and it was in this region that the insect has become most abundant and destructive. Whether or not Webster was correct in his theory of the migration of the insects from central America, it is certain that it was well distributed over the central prairies when these prairies were first broken up into farms.

According to most taxonomists there are two species of chinch bug occurring in this country. There are, at least, two different forms which have slightly different food habits. In the west and mid-west the insect is primarily a pest of small grain and corn, while in the east it is primarily a pest of grasses such as timothy and blue grass, and according to reports of some observers, does not feed on corn at all.

In all sections it feeds only on plants belonging to the grass family. At times when its food is very scarce it may insert its beak in some nearby plant to secure water. It has not been found possible to rear it on any plant other than a grass.

Besides this difference in food habits, there is also a difference in the form of the insects. In the west central valleys the insect is almost entirely long-winged, that is, developing in the adult stage to a form which is capable of flight and which has regular periods of flight migration:

First: From winter quarters to its food plants.
Second: A nuptial flight during mid-season, and
Third: A flight from its food plants to its hibernating quarters in the Fall.

The short-winged form is most abundant east of the Alleghanies. A recent statement from Professor O'Kane of New Hampshire is to the effect that in New Hampshire the chinch bug occurs in about equal numbers in short and long-winged forms.

Dr. C. P. Alexander states that the short and long-winged forms occur in Massachusetts in almost equal numbers. The same holds true of a small series of specimens which he has examined from Maine. If anything the long-winged form seems to predominate slightly. He thinks that the form occurring in Massachusetts is the variety *hirtus*.

Dr. W. E. Britton in Connecticut states that the short-winged form predominates and makes up from 75 to 80 per cent of the chinch bug population of that state.

The short-winged form is reported to be common in Ohio but is not the predominating form.

In Illinois the short-winged form is very rarely found.

Webster felt that a possible explanation of the abundance of the short-winged form along the coast might have been due to the long-winged individuals having been blown into the ocean during their migration. For a number of years I had the opportunity to observe the chinch bug on one of the low, sandy islands on the northeast coast of Massachusetts (Plum Island at the mouth of Newburyport harbor). There were always large numbers of them in the beach grass, so close to the water's edge as to be wet by the spray at high tide. Here the long-winged form was the most abundant.

It is through the midwestern area that the chinch bug causes the greatest damage. In this area the insect is essentially two-brooded. It hibernates in the adult form and probably in this form only. These hibernating adults seek shelter in a great variety of situations. Where the old native prairie grasses are abundant they will be found mainly in these grasses, especially in the *Andropogon* sp. It is not uncommon to find from 5 to 10 thousand bugs in a single six inch bunch of these grasses. In one case this year in Illinois over 16,000 bugs were taken from a single bunch of *Andropogon* which was approximately six inches in diameter at the base. Even where these grasses are abundant, some of the bugs will be found in other situations. Where these grasses are scarce, the common hibernating places are the edges of woodlands, the south slopes of ditch banks and roadsides, the bases of bunchy weed grasses such as barnyard grass, *Echinochloa Crus-galli* (L.); foxtail grass, *Alopecurus* L.; in Kentucky blue grass, *Poa pratensis* L.; especially where this grass is growing in clumps, in tickle grass, *Panicum capillare* L.; under loose bark of trees, logs and posts, in litter accumulating about the south and west sides of hedge rows, and in fact almost any situation that will provide them shelter during the winter. They have frequently been taken in large numbers under the loose shingles of houses.

In the spring the bugs fly out of winter cover on the days when the temperature is above 70° and the sun is shining. Before flight there may be considerable activity in winter quarters, the bugs crawling about and mating. Our observations in Illinois show no general flight until the temperature is above 70° and during sunny days. There is a considerable period over which the bugs are moving out of winter quarters, this movement often extending over three weeks to a month when warm periods alternate with periods of cool, wet weather. They settle in any type of grass which is green and succulent but show a strong preference for barley and spring wheat. They do not always remain in the same field but may alight in one field, crawl about for a time, and then take flight to some other point. Once settled in the field they will seek the shelter of any protective litter on the ground and will be found more abundant in fields where small grain has been planted in corn stalks or that have received a top dressing of straw or manure during the winter.

Oviposition starts during the first warm days and continues usually for about a month. The young nymphs start hatching from the eggs and may be nearly full grown before the last eggs have been laid. By the time of small grain harvest nearly all of the overwintering adults have died and the young bugs are beginning to reach the adult stage, having gone through five moults. The adults and nymphs either migrate on foot or by flight to fields of corn where eggs of the second brood are deposited. In a normal year second brood bugs begin to reach maturity by the latter part of August and by the last of that month or the first of September the return movement to winter quarters is well under way. In the region of Urbana, Illinois, this movement into winter quarters continues until about the first of November.

The chinch bug is normally two-brooded throughout most of its range but this may vary somewhat. There was unmistakeable evidence of a

third brood in some of the drouth area of west central Illinois this season.

Mr. R. O. Snelling of the Bureau of Plant Industry, Lawton, Okla., is sure that a third brood of chinch bugs is of frequent occurrence there. Quoting from a recent letter from him:

> "A full third brood of chinch bugs has been observed under field conditions at Lawton, Oklahoma, each year during the five years, 1930 to 1934 inclusive. A third brood was observed under cage conditions in 1933, this being the only year that a cage was used. The long growing seasons and abundant food supplied by wheat, oats, barley, corn, sorghums, broomcorn and Johnson grass seem to offer an explanation for the occurrence of a third generation."

The chinch bug is more susceptible to weather conditions than many of our common insects. Prolonged periods of damp weather during the active season make a condition favorable for the growth of certain fungus diseases which attack the insect and during such periods these diseases spread with great rapidity through fields where the insects are abundant.

Beating rains during the time of hatching of the young bugs may almost completely wipe out a heavy infestation. The effect of such rains is very largely mechanical, knocking the bugs off the plants and imbedding them in mud where they are unable to get out. Millions of bugs are, of course, knocked off the plants and actually washed out of the field. One of the most serious out-breaks of recent years occurred in Illinois from 1910–1915. This outbreak was terminated by heavy rains in June and August of 1915. Very few diseased bugs could be found in the field at any time.

It is mainly the two weather conditions mentioned in the two foregoing paragraphs that have in the past been responsible for terminating serious outbreaks. Either condition may be effective but must occur at the proper time in the development of the bugs.

Wet weather during the winter or early spring has very little effect in reducing their numbers.

The principal reason for the tremendous abundance of chinch bugs in the midwest area is that the system of farming in the area is almost ideal for promoting chinch bug abundance. Under the conditions existing on the native prairie the overwintering bugs coming out of their hibernating quarters must have found an abundance of succulent food in the tender grasses growing there in the spring. By late June or July, when the spring brood bugs matured, most of the prairie grasses had become hard or during dry years, had dried up so that the second brood of bugs never had a great abundance of satisfactory food on which to mature.

Under our present agricultural system, however, we provide an almost unlimited supply of food for the first brood bugs in our crops of small grain such as rye, wheat, barley and oats. We also provide an ideal condition for production of second brood bugs and all the food that they can eat in our fields of corn. If the chinch bug was to arrange matters according to its own liking, it could probably not do any better than man has done for it. In fact, if weather conditions are favorable it con-

tinues to multiply and increase over a period of years and reaches an almost unbelieveable abundance.

It is, throughout its life, primarily a sun-loving insect. Its hibernating places are chosen on sunny slopes, selecting the places where the cover is exposed to the sunshine of the early autumn afternoons. When it flies to fields of grain it selects those which are thinnest, where it will have a considerable amount of exposure to sunshine. It is possible that this one reaction in its behavior will tend to make it an increasingly important factor in our midwestern agriculture, that is, the insect avoids heavy stands of grain or grain and corn which is growing in the rich, more fertile soils. Now that the land in this area has been farmed for a hundred years or more, it is, on the whole, becoming much less fertile. This means thinner stands of grain and corn and with these thinner stands the chinch bugs are finding conditions more to their liking than they have in the past.

The fungus diseases already mentioned are probably the most important of the chinch bug's natural enemies, aside from adverse weather conditions. It has no especially important parasitic or predacious enemies. Larvae of certain lady bugs, the larvae of the lace-winged flies, both Chrysopa and Hemerobia and the insidious plant bug, *Triphelps insidiosus*, feed readily on the young bugs. It is also preyed upon by some of the predacious beetles and to a limited extent by certain birds.

Probably the most important insect enemy of the chinch bug is the egg parasite, *Eumicrosoma beneficia*. This parasite, first discovered by the late Professor McCulloch in Kansas in 1913, is very abundant throughout the midwest range of the chinch bug and while it probably never accounts for the disappearance of an outbreak, it may be present in sufficient numbers to destroy 20 to 25 per cent of the eggs.

A study of the chinch bug parasites and predators carried on in Illinois in 1914–1917[4] shows that at that time these insect enemies were present in some fields in sufficient numbers to destroy two million chinch bugs per day over a 40 acre field. However, when one considers that chinch bugs frequently occur in numbers of 50 to 100 million over this area, it is evident that all of these insect enemies together were making no appreciable decrease in the numbers of bugs. As many as 7½ bushels (This would be equal in number to about 60 million bugs.) of chinch bugs have been caught in one week in post holes along the barrier on one side of a 40 acre wheat field.

While the methods of combating the chinch bug have been improved considerably during the past twenty years, we are still at a loss for any method that will destroy the bugs when they are distributed in destructive numbers over hundreds of thousands of acres of small grain or later in the season, throughout the fields of corn. At the present time the most effective means of fighting the chinch bug are:

Directly

1. While they are in winter quarters, by burning.

[4]Journal of Economic Entomology, Volume 11, No, 5, page 415, 1918.

2. While they are migrating from small-grain fields to corn, by the use of barriers and traps.

INDIRECTLY

1. By the use of chinch bug immune crops.
2. By the use of resistant varieties of crops on which the bugs feed.
3. By planting certain crop mixtures.
4. By the proper rotation of crops.

Attacking the bugs by burning when in their hibernating places was early advocated as a means of control. Barriers used to combat the bugs at the time of their migration from small grains to corn have been in use for a long period. Dust barriers were used nearly 80 years ago. In 1864 barriers were in use in Illinois and Wisconsin which were made by setting boards on edge in the soil and wetting the exposed edge either with kerosene or coal tar. According to LeBaron, crop barriers, that is, the sowing of a strip of an attractive crop between the small grain and the corn, were used as early as 1852.

At least 50 years ago barriers made by pouring a narrow line of coal tar on the ground were in common use in Illinois. The coal tar barriers were the main ones depended upon until the development of the creosote barrier in Illinois in 1913–1914.

During chinch bug outbreaks it has been found impossible, due to the habits and numbers of the insect and to its general distribution over fields, to use insecticides against it except in a very limited way. While some attempts have been made to gas the insect in grain fields, these have not as yet been worked out to a point where they are practical under farm conditions. Certain contact sprays can be used against the bug when they are attacking the first rows of corn in the field.

Some studies were conducted as to the effectiveness of the abandonment of wheat. A particularly thoro investigation on this subject was carried out by Dr. Forbes from 1882–1888. His conclusions were that severe drouth during the latter part of the summer may considerably reduce chinch bug numbers by the drying up and lessening of their food supply. He felt, however, that the discontinuance of wheat alone would be of little if any value in reducing the number of bugs. He felt that numbers of bugs would not be greatly reduced unless all small grain growing was discontinued and even then that bugs would breed in rather large numbers in timothy or blue grass if these two grasses were generally grown in the area where the bugs were already abundant. He felt that the greatest good might be accomplished by discontinuing the growing of corn but that this was hardly practical under farm conditions as generally encountered in the midwest.

Kerosene emulsion was used as a contact spray for combatting the chinch bug by Dr. Forbes in Illinois in 1882.[5] Later other contact insecticides have been used in a limited way, especially the nicotine compounds.

[5]Twelfth Report of the Illinois State Entomologist, Vol. 20, 1882, p. 57.

During the past 15 years considerable progress has been made in combatting the insect by the proper use of chinch bug-proof crops and by the development of chinch bug resistant strains of sorghums and corn. During the early outbreaks of the insect the midwest farmers had little choice in the selection of crops which they could use. No legume crop was grown that could be substituted for small grain, and it was practically impossible to discontinue the growing of corn.

The new legume crops that have been introduced into the central west during the past 25 years have made it possible to fight the chinch bugs much more effectively. The general growing of soybeans, cowpeas, alfalfa and other legumes has given the farmer a new weapon with which to fight the bugs. The substitution of these entirely chinch bug-proof crops has made it possible during chinch bug outbreaks to greatly decrease the acreage in susceptible crops, such as small grains and corn, and substitute for them crops of high value in money returns and at the same time crops which will benefit the land if turned under for soil improvement. We have been able to utilize soybeans more than any other crop in our fight against the chinch bug. Grown by themselves, they are entirely immune to attack. They can also be planted with corn and because of the shade which they form about the base of the corn stalks, render such corn unattractive to the bugs and in this way increase the yield of corn.

In 1917 some studies of resistant varieties of corn were started in Illinois and these have been continued up to the present time. As a result of these studies, in cooperation with the Plant Breeders and particularly with Dr. J. R. Holbert, Senior Agronomist, Bureau of Plant Industry, United States Department of Agriculture, we have developed several strains and varieties of corn which are very markedly resistant to the second brood chinch bug. These varieties can be depended upon under heavy chinch bug infestation to produce from two to three times the amount of sound corn which could be produced by some of the more susceptible corn varieties.

The work in Kansas and Oklahoma has developed certain strains of grain sorghums which are very highly resistant to second brood chinch bug attack.

By the proper arrangement of the crops on the farm and the proper balancing of the crops during chinch bug years, much can be done towards lessening damage. It is also possible to work out certain crop rotations that can be practiced with profit on most farms in the chinch bug infested areas and which will reduce damage by the bugs to a minimum.

The work of Forbes[6] in Illinois and Snow in Kansas seemed to show that certain of the chinch bug fungus diseases could be artifically propagated and disseminated and that they would aid greatly in reducing chinch bug outbreaks. Further careful studies of this, however, show very clearly that if conditions in the field are not favorable to the spread of chinch bug fungus, it is useless to put out diseased bugs or fungus

[6]Twelfth to Sixteenth (1882–1888) Reports of the Ill. State Entomologist.

spores in the field. Long before his death, Dr. Forbes became firmly convinced that the conclusions drawn from his early work were erroneous and that there was nothing to be gained by the artificial dissemination of any of the diseases of chinch bugs which are known at this time.

Summing up what has been done in gaining a knowledge of this insect, its habits, life history and methods of control we can, as entomologists, feel a justifiable pride in many of the accomplishments of the past 50 years. There is still much to be done in developing better and more effective methods of controlling this very serious pest. Better means should be found of combating the insect during the first brood while it is concentrated in fields of small grain. It is certainly still possible to improve our barriers used for combatting them at the time of migration from the small grain to the corn. Aside from the development of resistant strains of corn, we are entirely lacking in a practical method for combatting the insect while the second brood is being produced in our corn fields. We are also particularly in need of a control that can be applied to garden patches of sweet corn or to large fields of sweet corn grown for canning.

There is also still much to be learned in regard to certain reactions of the insect. We are almost entirely ignorant of the distance which the insects cover in their flight to winter quarters, from winter quarters, or during the nuptial flight in mid-summer. There are also many questions to be answered as to just why the bugs will concentrate in certain fields of small grain and leave others almost untouched.

Certainly the entomologist of the future has a very profitable field of effort in developing better means of controlling this insect. Even with all of our present knowledge and organization the chinch bug has, during the past year, caused more than a $100,000,000 loss in the upper Mississippi Valley and threatens to cause even greater losses in 1935.

THE ENTOMOLOGICAL PHASES OF THE DUTCH ELM DISEASE

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It is impossible to discuss the entomological phases of the Dutch elm disease intelligently without considering the background of the disease itself.

Though the place of origin of the so-called Dutch elm disease is unknown, it was first recognized in Holland. Spierenburg (1921) described a die-back of elms which first appeared in South Holland in 1919, without definitely assigning a cause. Later Schwarz (1922) described a new species of fungus, *Graphium ulmi*, from cultures obtained from wood of diseased elms. This she reported to be the primary factor in the death of the elms in Holland. The mycological work of Schwarz was confirmed and extended by von Linden and Zenneck (1927), Wollenweber (1927), Buisman (1928), and others. Buisman (1932 a) found and described the perfect stage of the fungus as *Ceratostomella ulmi*, an Ascomycete.

From the time of its discovery, the spread of the disease throughout Europe was rapid. It is difficult to date definitely its appearance in the various countries, due to the fact that previous to the time of isolation of the causative organism, evidence as to its presence is based on symptoms, rather than on isolations of *Graphium ulmi*. However, it appeared almost immediately in Belgium (Anonymous, 1925), France (Guyot, 1921), and Germany (Anonymous, 1922), and has now been reported from a total of fifteen European countries.

Injury from the disease in Europe has been severe. The opinion has been expressed by European pathologists that the elm stands of Central Europe are doomed (Kaiser, 1931). At least two Dutch pathologists have stated that in their opinions the present stand of elms in their country will be entirely lost. In Austria Schwarz (1934) reports that fifty per cent of the elms are diseased, and that there is little hope of saving the remainder. In Italy Sibilia (1934) states that the percentage of infected trees runs up to as high as fifty per cent, in the province of Emilia, though in other provinces it is not over from ten to fifteen per cent.

The probable method of introduction of the disease into the United States, and its history in this country, have been reported to this society (Beattie, 1934), and need not be repeated here. To summarize the record of diseased trees discovered to date, the following data are given: Ohio, 10 trees at Cleveland, 1 at Cincinnati; Maryland, 1 tree at Baltimore; Indiana, 4 trees at Indianapolis; Virginia, 1 tree at Norfolk; the tri-state area of New Jersey, New York and Connecticut, over 7600 trees, in an infected area of about 2500 square miles, within a radius of about forty miles of New York City, distributed by states as follows: New Jersey, 57% of the area involved and over 5000 infected trees; New York, 34% of the area involved, and about 2500 infected trees; Connecticut, 9% of the area involved, and 57 infected trees. One of the Connecticut trees, that at Old Lyme, was well separated from the remainder of the infected area of that state.

An analysis of the distribution records indicates that there have probably been at least six separate introductions: at Cleveland and Cincinnati, Ohio; Indianapolis, Ind.; Baltimore, Md.; Norfolk, Va.; and the tri-state area. Only one of these introductions, that into the tri-state area, was into a region previously infested by the smaller European elm bark beetle, *Scolytus multistriatus* Marsham, to which fact is attributed the comparatively wide spread of the disease in that area.

Felt (1935) has pointed out that there has been a twenty-fold increase in the number of trees known to be infected, and a three-fold increase in area involved since the first determination of the infected region in the tri-state area. However, the record of tree discoveries does not necessarily indicate either the time of first appearance, or the rate of spread of the disease. For instance, from one of the Indianapolis trees discovered this year, *Graphium ulmi* was isolated from the 1926 growth ring (May, 1934 b). One of the Cleveland trees located this year yielded *Graphium ulmi* from the 1929 ring. From New York trees located this year *Graphium ulmi* has been isolated from the rings of one, two, three,

or more seasons past. While it is not known definitely that the fungus will not grow from the outer to the inner rings, it is assumed that it usually does not, and the earliest ring infected probably marks the date of infection.

The importance of the disease in the United States at present is indicated by the number of trees infected and the area involved. It has been estimated that there are 3,000,000 elm trees in the tri-state area scouted, in which about 7600 diseased trees have been found (Worthley, 1934), giving a percentage of infection of .25%. Rankin (1934) has given figures on percentage of infection in New York. In the infected area of Westchester Co., .72% of the elms are infected; in the Bronx, 2.5%; in Manhattan, .28%; in Staten Island, 3.06%. Within these areas, the smaller survey areas, of approximately two square miles, show higher percentages in some cases. Percentages of infection in individual survey areas are as follows: Westchester Co., 2.5%, 2.3%, 15 areas of from one to two per cent, the remainder less than 1%; Bronx, 13.4%, 11.7%, 7.2% and 5.3%, for the four highest; Staten Island, 8.2%, 7.7%, 4.8%, 4.7%, 4.3% and 4.3% for the six highest. The destruction caused by the disease in its present restricted distribution is, however, of slight importance to that anticipated if it should spread over the entire United States.

The pathogenic organism lives in the sap wood of any part of the tree, causing a loss of function of the conducting vessels. The result is a wilting of the parts affected. The disease is evidenced first by yellowing, browning and dropping of leaves, later by the presence of entire dead branches, and finally by the death of the whole tree. The progress of the disease may be rapid, entirely killing a tree in a short time, or slow, requiring several years to bring about the death of the tree. Recovery, in some cases complete, has been reported from England. Internally, infected trees show a dark discoloration of the sap wood in the form of solid bands or streaks. This discoloration may be immediately under the bark, or be buried by a superimposed layer of healthy wood, showing in cross section as a solid line or stippled ring or arc.

The presence of elm bark beetles has been associated with the disease from the time of its discovery. The first paper definitely referring to the disease, that of Spierenburg (1921), mentioned the fact that *Scolytus scolytus* Fabricius, the large elm bark beetle, was found in many diseased trees, but stated that in her opinion the beetles attacked secondarily. Other early observers considered the beetles the primary causes of the dying of the trees (Malaquin, 1923; Knop, 1928; Kaiser, 1931). Wollenweber and Stapp (1928) noted the frequent appearance of *G. ulmi* in the larval beds of *S. scolytus*, and suggested that elm bark beetles were one factor in the spread of the disease. Through the researches of Betrem (1929), Roepke (1930), and Fransen (1931) in Holland; Prell (1930) in Germany; and Grossmann (1930) in Switzerland, it was established to the satisfaction of the European students of this disease that *S. scolytus* and *S. multistriatus* were indeed the vectors of *G. ulmi*. Their findings were the more significant, since the plant pathologists had been unable to demonstrate transmission in nature by any other means. Con-

trol measures advocated in Europe are now based on these findings, which are supported by the following evidence:

1. The beetles are definitely attracted to diseased trees, which they enter in large numbers for the purpose of laying eggs.

2. Under proper conditions, the fungus produces its fruiting bodies, coremia, in pupal cells which are still occupied by living pupae, as well as in the maternal tunnels of the parent beetles.

3. The emerging beetles have been found to bear viable *G. ulmi* spores, both externally and internally. Cultures of excrement also show presence of *G. ulmi*.

4. Newly emerged beetles pass through a period of maturation feeding, lasting from a week to ten days, during which time they feed on the twigs of elms, preferably healthy ones (Fransen, 1931). It is at this time that they inoculate the healthy tree with *G. ulmi*.

This last point, the crucial one, is supported by the finding of typical *Graphium* discoloration, positively identified as due to *G. ulmi* by culture methods, extending both up and down the twigs from *Scolytus* feeding punctures; and by successful experimental transmission by *S. scolytus* obtained by Fransen (1931) on two branches of a single elm, from one of which *G. ulmi* was isolated.

The greater part of the work on the transmission of *G. ulmi* has been done with *S. scolytus*, which is more numerous and aggressive than *multistriatus* in Europe. However, Fransen (1932) has devoted a paper to the latter species, which he finds gaining in numbers in relation to *S. scolytus* in Holland, and whose importance as a vector he considers underestimated. Other bark beetles mentioned in Europe in connection with the disease are *Scolytus sulcifrons* Rey (Goidanich and Goidanich, 1934), *Scolytus laevis* Chapuis (Kaiser, 1931), and *Ptelobius vittatus* Fabricius (Buisman, 1933 a, Schwarz, 1934).

In this country *Scolytus multistriatus*, the smaller European elm bark beetle, is receiving the greatest amount of attention as a vector of the Dutch elm disease organism. Since *S. scolytus* and the other insects mentioned above are not present in this country, it is natural that we should first investigate an insect which has proven itself important as a vector in Europe. Furthermore, distributional evidence, field observations, and experimental work point to this insect. The failure of the disease to spread from the outlying infections in Ohio and other places appears to be connected with the absence of this species in those places. *S. multistriatus* is the most abundant insect, though not the only one, living in the diseased areas under the bark of "Dutch Elm" trees, at least in the infected area of New York. Figures compiled from data assembled by the New York State College of Agriculture group investigating the disease during the past season, show that of the confirmed trees examined, 67.4% were infested by *S. multistriatus*, 54.4% by *Saperda tridentata* Olivier, the elm borer, and 10.9% by *Hylurgopinus rufipes* Eichhoff, a native bark beetle. The coremia of the fungus are abundant in the pupal cells and maternal tunnels of *S. multistriata*, though present also in the tunnels of other insects. Typical feeding scars of the beetle are found practically without exception on diseased trees in New York,

as well as in New Jersey (May, 1934a). Lastly, experimental transmission through the agency of this beetle has been accomplished, in a small percentage of trials, at the United States Department of Agriculture laboratory at Morristown, N. J. (Middleton and Buchanan, 1935).

In spite of this apparently conclusive evidence that *S. multistriatus* is the vector of *G. ulmi*, there are still questions regarding the transmission of the fungus which need to be clarified. The most important of these is: why, with a large number of experimental beetle transmission trials, so few infections result. We must determine the conditions of successful transmission, whether they lie in the beetle, the fungus, the tree, environmental conditions, or combinations of these, so that in our attempts to control the disease we may eliminate or minimize these conditions.

Insects other than *S. multistriatus* must still be considered possible carriers of the disease. Since the disease organism is carried mechanically, it is theoretically possible for any insect that has the opportunity to pick up spores from diseased trees, and deposit them in wounds of healthy trees, to act as a vector. The groups of insects under suspicion are wood and bark borers, such as the scolytid, *Hylurgopinus rufipes*, the cerambycid, *Saperda tridentata*, the curculionids, *Magdalis spp.*, the buprestids, and the cossid, *Zeuzera pyrina* Linnaeus; the leaf feeders, such as the elm leaf beetle and the canker worms; the sap suckers, such as plant lice and leaf hoppers; and those insects which lay eggs in wood, such as tree crickets, tree hoppers, and cicadas. Of these, the bark and wood borers in general, and *Hylurgopinus rufipes* in particular, against which specific evidence has recently been presented (Clinton and McCormick, 1935), are most likely to be of importance, being more similar to *S. multistriatus* in habits.

Scolytus multistriatus. Marsham—This insect (Figure 41, 9) is a small bark beetle, from 2 to 3.5 mm. long, with shining black, finely punctured pronotum; pitchy red elytra, lined longitudinally with many finely punctured striae; and straw colored legs and antennae. It is easily distinguished from *S. scolytus* and most of the other species of the genus in our country, as well as from *H. rufipes*, by the presence of a strong horizontal projection on the second ventral abdominal segment.

Hosts.—It confines its attacks almost entirely to elms, though it has also been recorded from plum, aspen and ash (Escherich, 1923; Nunberg, 1930).

Distribution.—It occupies all of Central Europe. In this country its distribution has recently been given by Knull (1934) as including eastern Massachusetts, western Connecticut, southern New York, more than the northern half of New Jersey, and eastern Pennsylvania. Previous to Knull's survey it had been reported by Hollister (1920) from northern Virginia, Detroit and Chicago.

Life History and Habits.—*S. multistriatus* breeds in recently killed or sickly and dying elm branches or trunks. Any part of the frame work of the tree may be attacked except branches and twigs less than about an inch in diameter. It has been mentioned before that the beetles are attracted in large numbers to trees weakened or killed by the Dutch elm

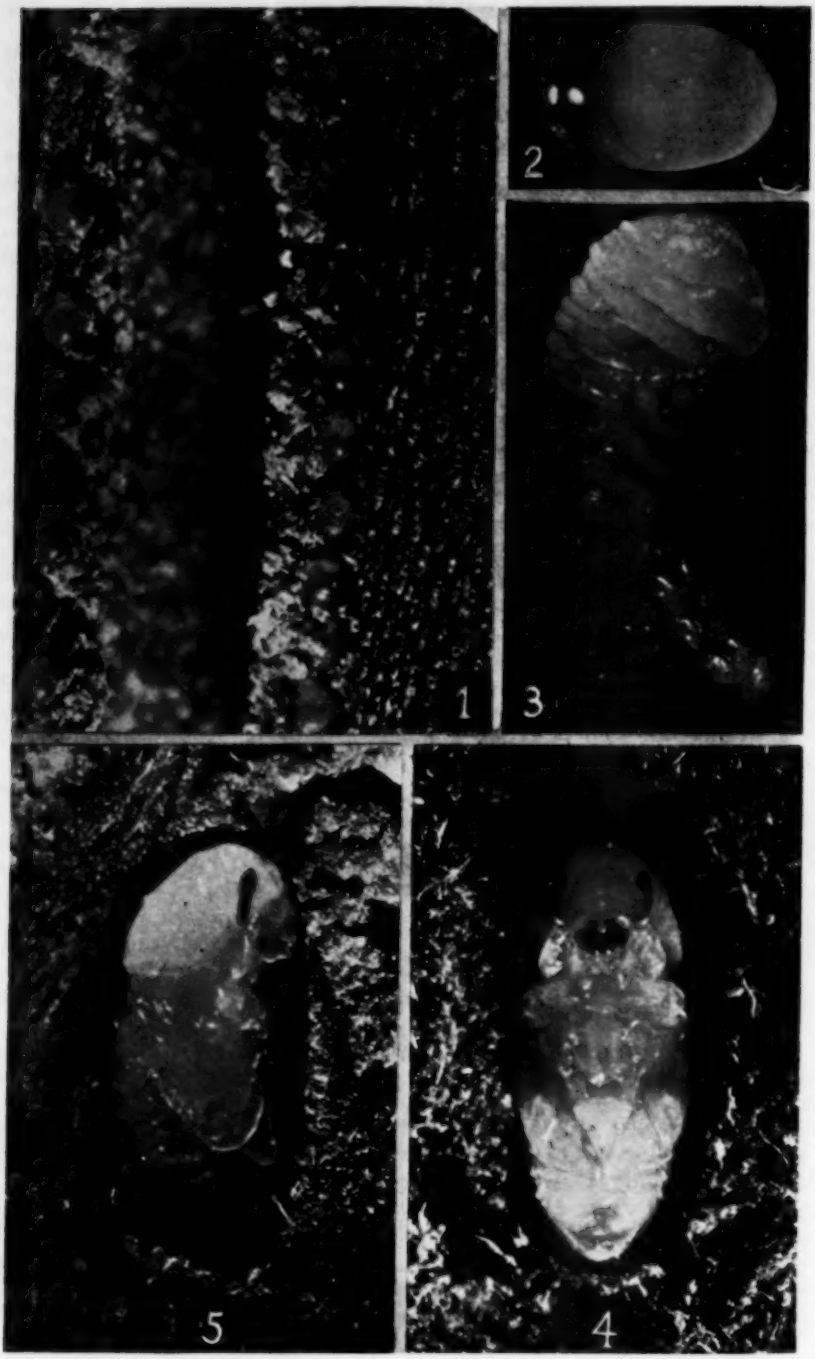

Fig. 40—Inner surface of elm bark, showing maternal tunnel of *Scolytus multistriatus* with eggs in position x 16.0; 2—Egg of *multistriatus* x 52.5

disease. While this may not be a case of specific attraction, nevertheless the disease apparently puts the tree in the proper physical and chemical condition to make it extremely attractive to the beetles.

The adult female enters directly through the bark, removing bits of bark material as she goes. This somewhat reddish saw-dust like material marks the opening of the entrance tunnel. The tunnel runs obliquely upward, or occasionally downward, until the wood is reached, when it is extended immediately under the bark, including a portion of the inner bark and a portion of the sap wood. Fransen (1932) gives the maximum length of the maternal tunnel as 8.5 cm. Measurements made this summer on infested trees in the New York area are as follows: American elm, 52 tunnels measured, maximum 7.5 cm., minimum .8 cm., average 4.5 cm.; English elm, 55 tunnels measured, maximum 7.2 cm., minimum .8 cm., average 4.8 cm. The male lives at the entrance to the tunnel, frequently coming to the outside to remove boring dust, relayed to him by the female. At the proximal end of the tunnel is an enlargement, the so-called nuptial chamber, which is also used as a turning chamber by the female.

The eggs (Figures 40, 1 and 2) are laid at rather regular intervals along both sides of the tunnel. The female excavates the egg niche with the head forward, backs to the enlargement at the base, reverses position and backs into the tunnel. After having deposited the egg in the niche prepared for it, she again goes to the enlargement to reverse position, and enters head first to pack boring dust around the egg and excavate further. The adult beetles occupy the tunnel for several weeks, the female continuing to lay eggs as she extends the tunnel in length. Mr. Leonard Tuthill, working at the Cornell Dutch elm disease laboratory at Boyce Thompson Institute this summer, found that by removing the superimposed bark from the tunnels, and replacing it with a glass slide sealed in place, according to directions given by Swaine (1918), he could observe the progress of work in the tunnels. He found that active beetles tunneled from 2 to 14 mm. a day, with an average of 5.4 mm. for 24 beetle days at 27°C. Fransen (1932) gives the maximum number of eggs laid by a single female as 200, though the average is much lower. Tuthill found at least as many as 7 eggs laid per day in some cases, and probably more. The length of the egg stage as determined by him is a little less than a week at 27°C. The egg is shining white, about .6 by .4 mm.

Upon hatching, the larvae (Figure 40, 3) begin their feeding tunnels at right angles to the maternal tunnel. They later diverge more or less, as increase in size necessitates space (Figure 41, 1–8). The larval tunnels are packed solidly with frass, among which may be found the cast larval skins. Our studies this summer indicate that there are five larval molts.

Near the end of the larval life, the insect tunnels into the bark, hollows out the pupal cell, passes through a prepupal stage one to two days, and pupates. The pupa (Figure 40, 4 and 5) is white when newly formed, and bears paired dorsal projections on the caudal segments of the abdomen. After a pupal stage of 5 to 6 days at 27°C., the insect transforms to the adult. After a few days spent within the pupal cell, it emerges

3—Larva of *S. multistriatus*, x 16.0; 4—Pupa of *S. multistriatus*, ventral aspect, in pupal cell, x16.0; 5—Pupa of *S. multistriatus*, lateral aspect, in pupal cell, x16.0. (All photographs by L. P. Flory, Boyce Thompson Institute.)

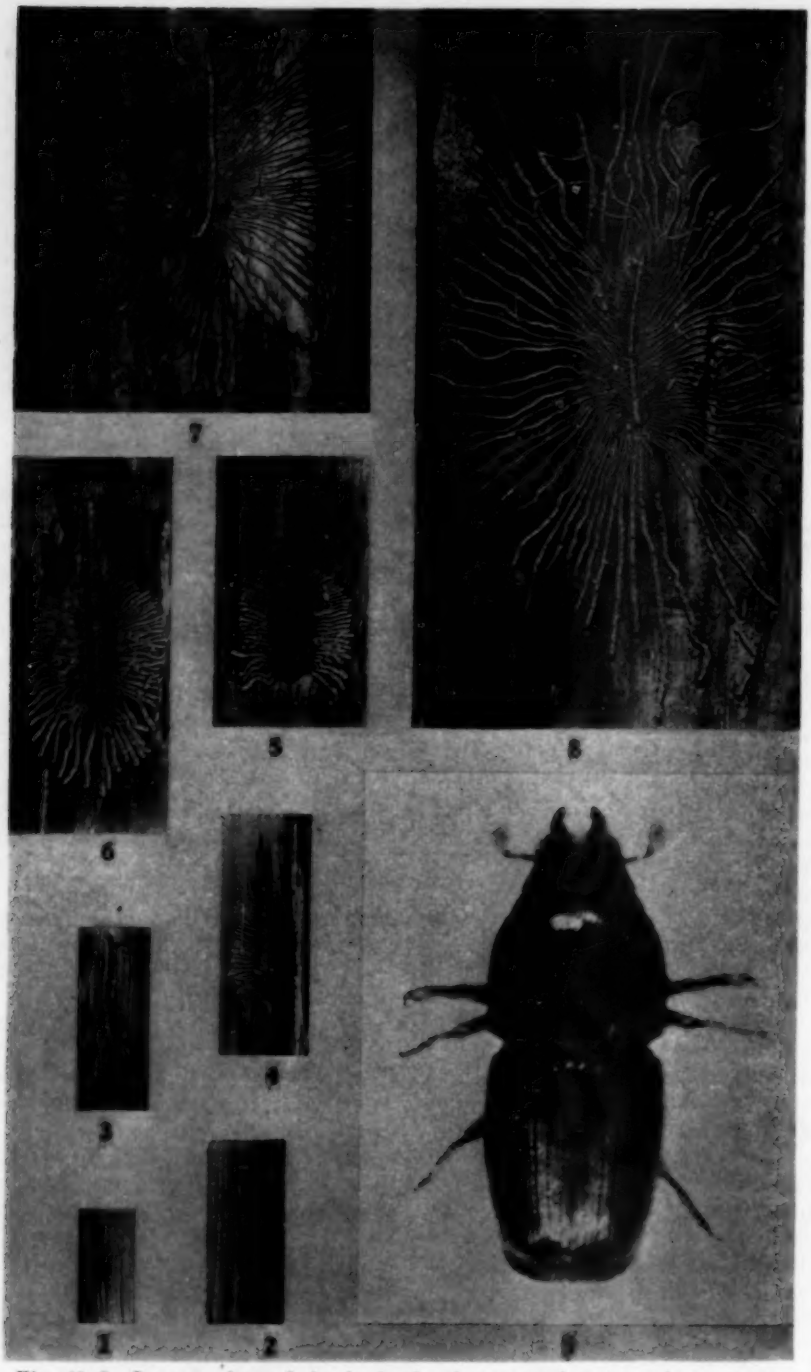

Fig. 41–8—Inner surface of elm bark, showing successive stages in construc-

through the bark, leaving the characteristic "shot-hole." The beetle now feeds on the twigs of healthy elms, particularly at the crotches, later entering a sickly or dead limb or trunk for the renewal of the cycle. In this country the beetle is said to have two and a partial third generation a year, and to be present in the field as an adult all during the warm season, from the middle of May until after the middle of September, as reported by Middleton (1934). Our records for New York show the continuous presence of all stages in the field from the time we first established contact with the insect, at the beginning of our work, on July 17, until Oct. 1; eggs and pupae were observed up to Oct. 9. The insect winters in the larval stage.

NATURAL ENEMIES.—As natural enemies of this species, birds, nematodes, hymenopterous parasites, predacious beetles and mites, and parasitic fungi have been recorded.

CONTROL OF THE DUTCH ELM DISEASE.—In Europe, two main types of control are given prominence. These are, first, the removal of infected trees, and disposal of the parts so as to prevent the emergence and flight of the bark beetles. This is accomplished by removing and burning the bark of the larger parts, together with the smaller branches and twigs; by submerging in water; or by treating the surface of the bark with carbolineum. Second, an attempt is being made to find species or varieties of elm which are immune, or sufficiently resistant to the disease so as to suffer no great damage, for replacements. Buisman (1931, 1932b, 1933b, 1934), who has been studying this phase of the problem for several years, has found the Asiatic species in general, and the Siberian elm, *Ulmus pumila* Linnaeus and its variety *pinnato-ramosa* Henry in particular, to be resistant, though not immune to the disease.

Other controls being given prominence in Europe are: Tree injections, for the control of the fungus; cutting back of infected parts, in an attempt to extirpate the disease from the individual tree; spraying with arsenicals, in an attempt to kill or repel the feeding bark beetles, and hence prevent infection; propagation of parasites of bark beetles; use of trap trees to attract the beetles.

In Holland, control is compulsory, and responsibility for removal and disposal of diseased trees, located by the Dutch forest and pathological service, is placed on the proprietor.

In most of the states of Germany responsibility for reporting sickly trees to the plant protection stations, as well as for removal or cutting back as directed, is placed on the land holders, infringements being punishable by fine or imprisonment.

In Italy emphasis is being placed on the use of resistant forms, and *Ulmus pumila* is being used as a replacement tree.

In England the recommendations are that severely infected trees be removed and destroyed; that slightly injured trees be given no treatment, except for the cutting back of larger trees, since they may recover.

In this country a determined effort is being made to eradicate the disease by destroying every tree found to have the disease as soon as possible after its discovery. This method accomplishes three purposes: Destroying the known reservoirs of the disease; destroying the insect in-

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tion of maternal and larval tunnels of *S. multistriatus*, x½. (Photographs by L. P. Flory.); 9—Adult *S. multistriatus*, x 20. (Photograph by Dr. P. W. Claassen, N. Y. State College of Agr.)

habitants of diseased trees, which might otherwise emerge and carry the disease to healthy trees; removal of breeding places for additional insect vectors. The known infected area was scouted several times during the past summer, suspected trees were tagged and sampled, the samples being sent to the U. S. D. A. Dutch elm laboratory at Morristown, N. J., for confirmation. Following positive confirmation of the samples, the trees were cut down and burned, and the stumps peeled and coated with creosote. An accessory control measure is the contemplated removal and destruction of dead and dying trees within the infected area, not necessarily known to be harboring the fungus, but acting as breeding places for the insect vectors. By thus reducing the population of the transmitting insects to a minimum, spread of the disease during the coming year should be greatly reduced.

Felt (1933, 1934) has advocated the general adoption of the practice of tree sanitation, not only within the area known to be infected with *G. ulmi*, but in the whole region where *S. multistriatus* is known to occur. This involves: Removal and burning of dead and dying elms and parts of elms; spraying for leaf feeders, such as elm leaf beetle and canker worms, whose attacks so weaken trees as to render them liable to bark beetle attack; fertilizing and pruning where necessary. There can be no question of the desirability of this procedure, not only as a possible protection against the Dutch elm disease and a means of reducing the bark beetle population, but also as a general means of increasing the beauty and vigor of our elms. It should be mentioned, however, that European work, as well as observations made in this country, indicate that healthy, as well as sickly and undernourished elms, are subject to the attacks of the disease.

The efficacy of spraying against the beetle itself, considered ineffective in Europe (Fransen, 1931), deserves a thorough trial before being given up as hopeless.

What will be the result of the present eradication campaign is uncertain, and will be for some time. Among the factors which favor its ultimate success are:

1. The relatively early attack on the problem. This may be more apparent than real, since, as has been mentioned above, *G. ulmi* has been isolated from 1926 wood in this country. If it is true that the disease has been present since that time, we may console ourselves with the fact that it has not spread rapidly in the intervening years.
2. The absence in this country of *S. scolytus*, the reported chief agent of spread in Europe. To be sure, we do not know that *S. multistriatus*, removed from the competition of *S. scolytus*, may not equal or surpass in numbers and effectiveness the combination of the two species in Europe. However, the fact that *multistriatus* is less aggressive than *scolytus* in Europe appears to be favorable.
3. The present restricted distribution of *S. multistriatus* in this country.
4. The apparently slow rate of spread of *S. multistriatus* since its introduction into this country previous to 1909 (Chapman, 1910).
5. The low percentage of experimental infection of healthy trees obtained from *S. multistriatus*.

Definitely unfavorable factors are:

1. The high susceptibility of the American species of elms to the disease.
2. The present great abundance of *S. multistriatus* in and adjacent to the infected area.
3. The occasional appearance of outlying infections, not continuous with the main infection. These are difficult to locate, and may form new centers of dispersal of the disease.
4. The difficulties of diagnosis, which necessitate laboratory culturing for positive identification.
5. The rather poor condition of the elms in the infected and adjacent areas.

Factors unknown, or not sufficiently well known, but of great possible significance in an eradication program are:

1. The possibility of the spread of the disease organism by agencies other than the insect vectors.
2. The range of flight of *S. multistriatus*.
3. The possibility of some of our native elm insects acting as important vectors of the disease.
4. The possibility of the development of control measures either here or in Europe which will increase the effectiveness of the control measures now being used.

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MR. O. N. LIMING: I would like to ask if Hollister's report on *Scolytus multistriatus* in Detroit has been confirmed.

MR. READIO: I have no information on that. I looked up that particular reference of Hollister's. It is true that it is reported from Detroit and Chicago.

MR. HOLMAN: I would like to ask if you would recommend what Felt recommends as a general condition of betterment. What would be your recommendation?

MR. READIO: We have no recommendation. Certainly, there is no question of the desirability of adopting this program. My feeling is that at the present time we cannot tell an elm owner that by adopting these measures he is going to insure his trees not getting Dutch elm disease. In fact, I am relatively sure that is not an insurance. Nevertheless the general adoption of this measure would undoubtedly reduce—and if it were done thoroughly over a whole region, it would do away with the bark beetle. According to our theories of the distribution of the disease, that should do away with the occurrence of new infections.

MR. O. N. LIMING: There is one comment I want to make. In 1933 our men in the field quite commonly observed in November adult Scolytus beetles. However, this fall—probably at least associated with some cool weather the latter part of September—the presence of the adult beetles was definitely reduced and probably eliminated.

MR. D. O. WOLFENBARGER: I would like to ask if any variation was noticed in the elm trees infected with the Scolytus beetles north of the district about New York City.

MR. READIO: Yes. It is true that as you go north from New York City the infested trees become much less in number and, of course, it is also true that the amount of infection becomes less. We did find that down in the Bronx region, particularly around Pelham Bay, Scolytus did seem to be much more numerous than farther north in Westchester County.

A METHOD FOR COMPARING THE OVICIDAL PROPERTIES OF CONTACT INSECTICIDES

By E. P. BREAKEY and A. C. MILLER, *Crop Protection Institute Investigators, The Ohio State University, Columbus, Ohio*[1]

While planning a series of tests for obtaining data on the ovicidal properties of the various substances commonly used as contact insecticides, the writers were able to find very little in the literature which would assist them in developing the necessary technique. The procedure followed in sterilizing the eggs of the blowfly, *Phormia regina* Meig., preparatory to using the larvae in surgery, was suggestive, and served as a basis from which to work.

The eggs of the blowfly are first separated by shaking them vigorously in a 10 cm. test tube with normal saline solution. As soon as they are separated, they are washed in 5% formalin for 15 minutes or in bichloride of mercury 1 part in 2000 parts of 25% alcohol for the same length of

[1]The authors wish to acknowledge their indebtedness to the Department of Zoology and Entomology for the use of equipment and accomodations in carrying on these studies.

time. They are then poured on a small pad of cloth in a Gooch crucible and washed by pouring normal saline solution over them, the fluid being drawn away in a suction flask.

It occurred to the writers that such a procedure might be adapted to their needs, using insecticide materials instead of disinfectants. Accordingly, an attempt has been made to develop a procedure capable of standardization, using the eggs of insects of wide distribution, whose life histories lend themselves to such a practice. The growing interest in the ovicidal properties of contact insecticides, and the apparent lack of any common method for ascertaining and comparing these inherent qualities prompt the writers to outline in some detail the technique developed by them. The need for formulating some uniform testing procedure is evident, and it is hoped that other investigators will offer such changes and improvements as may seem desirable. The object is to develop a testing procedure simple enough to be carried out in a reasonably well equipped laboratory, and sufficiently uniform that the results may be comparable wherever they may have been made.

The determination of the lethal concentrations for the various substances tested is a biological test, and as such is subject to the variability which accompanies the reaction of the organism to the influences of its environment. This variability is inherent in the organism and can scarcely be controlled. However, it has been found possible to control, to a reasonable extent, such superficial variables as time, temperature, humidity, concentration and purity of the toxic substance, and the age and condition of the eggs. The ideal, of course, is strict reproducibility. The condition of the checks at the end of the tests has been the criterion of how closely we have come to providing an environment suitable for the successful incubation and hatching of the eggs.

This paper makes no attempt to establish lethal concentrations for the various substances tested, but serves solely to outline a procedure for making the necessary tests.[2]

The Angoumois grain moth, *Sitotroga cerealella* Olivier, is an insect of almost universal distribution, whose life history is admirably suited to such a procedure as that to be proposed. There is the added advantage that the technique for obtaining the eggs of this insect in large numbers is well known. In fact, there are commercial insectaries from which quantities of these eggs may be obtained at a very nominal cost, those used by the writers coming by air-mail from California Insectaries Inc., Glendale, California.

APPARATUS.—The following articles were available for making the tests, and, with few exceptions, are necessary equipment: a suction flask of one liter capacity; a suction pump with connections; a Büchner funnel, 10 cm. in diameter; about 100 Petri dishes, 9 cm. in diameter, with covers; a number of bottles of one liter capacity, with corks; several apothecaries measures of one liter capacity; several dozen test tubes, 10 cm. in length; pipettes of 1, 5, and 10 c.c. capacity; graduates of 100 and 250 c.c. capacity; a chemical balance; a binocular microscope; china pencils; and a supply of 9 cm. filter papers.

[2]See Halowax as an Ovicide, Jl. Econ. Ent. 28:358–365, for results obtained by this method.

PREPARATION.—It is essential that all apparatus be clean, for it is evident that traces of toxic materials remaining from previous tests are undesirable, since they may affect the results. The writers have made it a practice to clean all utensils coming in contact with insecticides in chemists' cleaning solution before using them again.

Care must be exercised in diluting the insecticides and in seeing that each dilution is properly labelled. Fresh dilutions of all materials, subject in any way to deterioration, should be prepared. It is often expedient to prepare a dilution representing the highest concentration of the material to be used in a series of tests, making further dilutions from this stock. The experimental error is reduced by preparing many times the volume of any dilution necessary for any one test. The following information is written on the cover of each Petri dish used: material and concentration, egg used, and date. The date may also include the hour of application.

If the eggs have not been mixed through the activities involved in obtaining them, it is best to see that they are, since the object is to be able to sample a uniformly mixed population. To facilitate in handling the eggs, a sheet of paper 6 cm. square is folded in half. Into the trough thus formed are distributed 400 or 500 eggs. With a little experience, it is possible to estimate rather closely the number of eggs in the fold. The eggs are next examined under the binocular microscope, and any dirt or crushed eggs present are removed. The trough and its burden of eggs is then deposited in a Petri dish and the cover replaced before attempting to prepare the next sample. This act of routine guards against accidental spilling of the eggs.

It greatly facilitates the counting of the eggs if the filter papers on which they are distributed have been ruled into eight equal sectors, using a hard lead pencil. A supply of these papers should be available before starting the tests. A small mechanical counter has been of great assistance, especially when running a series of tests involving the use of thousands of eggs.

When the suction flask has been connected to the pump and the Büchner funnel is in place, all is in readiness for treating the eggs with the various toxic substances to be tested.

PROCEDURE.—A clean test tube is filled about three-fourths full of the diluted insecticide and one lot of eggs is poured into it from the paper trough in which they had been placed. The test tube is then closed and eggs and fluid are agitated by gentle shaking. A sufficient supply of clean dry test tubes enables one to use a different tube for each material or concentration tested. The suction pump is started, and eggs and fluid are poured onto one of the marked filter papers which has been placed in the Büchner funnel, the fluid being drawn away by the pump. The partially dried filter paper on which the eggs have distributed themselves is then removed and placed on a dry filter paper in the Petri dish prepared to receive them. Checks are treated exactly the same, except that water alone is used. If a long series of materials is being compared, more than one check should be taken.

Sometimes eggs will adhere to the inside of the test tube. If the number of eggs should be limited and it is desirable to retrieve these, they can be washed onto the filter paper with additional fluid of the same material and concentration. The time elapsing from the moment when the eggs are poured into the fluid until they are placed in the Petri dish varied from ten to fifteen seconds.

Before using another insecticide, or a different concentration of the same material, it is best to clean the Büchner funnel. This can be done, in most instances, by flushing it out at the hydrant and drying it with a clean towel. However, a change from one material to another makes more thorough methods necessary.

It is evident from the above that this method is limited to the testing of toxic materials as solutions, emulsions, or colloidal dispersions.

The Petri dishes containing the eggs were arranged on a laboratory table where the direct rays of the sun did not fall on them. Incubation was at room temperature, so no counts were attempted until the incubation period had elapsed. The laboratory where the tests were made is in a basement room with concrete floor, walls and ceiling, and, according to hygrothermograph records, the temperature ranged from 75° F. to 80° F., the range often being less than that for an entire week. Checks incubated in an atmosphere of high relative humidity have given the best hatches. Such an atmosphere can be provided by spraying the insides of the covers of the Petri dishes with water, beginning the second day following the application of the toxic materials and continuing at 48-hour intervals throughout the incubation period.

At the end of the incubation period counts are made to determine the percentages of eggs killed by the various materials and concentrations. This is best done under a binocular microscope, counting the empty egg shells and unhatched eggs, a sector at a time. The filter papers should remain undisturbed until all are counted.

The eggs of the Mediterranean flour moth, *Ephestia kuehniella* Zeller, and of the short-tailed mealy bug, *Pseudococcus citri* Risso, have also been used to some extent. Like the Angoumois grain moth, the life history of the Mediterranean flour moth is admirably suited to our needs. From a small stock in the laboratory one may secure enough eggs to make tests on a rather large scale. As in the case of the Angoumois grain moth, the procedure followed in breeding this insect as a laboratory animal is well known.

The eggs of the short-tailed mealy bug are separated from the cocoon by gently brushing the cocoon about over a sheet of white paper. It will be found that the cocoon adheres to the brush as the eggs are liberated. The eggs of this insect are more easily injured by dessication than those of the moths and have a longer incubation period, all of which add to the hazards involved in their use. The best results have been obtained when a wet filter paper was placed under the one on which the eggs were distributed at the time they were treated with the insecticide.

We have also used the eggs of the blow flies, *Phormia regina* Meig. and *Lucilia sericata* Meig., and found them quite satisfactory. These adhere together in large moist masses as they come from the breeding

cages, and so must be separated by shaking in a test tube with normal saline solution. Water apparently does just as well. To secure samples for the tests, the fluid containing the eggs is agitated by shaking, and a quantity of fluid and eggs is drawn into a pipette (medicine dropper). With some experience it is possible to obtain the desired number of eggs at each sampling. The eggs settle quickly to the tip of the pipette and can be released into the test tube of toxic material by a gentle squeeze on the bulb. This can be done in such a way that only a drop or two of fluid goes toward diluting the toxic solution. From this point the procedure is the same as that used in treating eggs obtained in a dry condition, with the exception that the partially dried filter paper on which the eggs are distributed is placed on a moist filter paper in the Petri dish. The eggs of blow flies require an atmosphere nearly saturated with moisture, hence a moist filter paper is used instead of a dry one.

There are several advantages to be gained from the use of the eggs of the blow flies not to be obtained from the use of those mentioned earlier in this discussion. They can be obtained in enormous numbers from a small set-up in the laboratory. The incubation period is short, only twelve hours at the temperature of our laboratory. This is a desirable feature since it reduces hazards to a minimum and enables one to repeat his tests at short intervals. The egg is large, easy to handle, and has a good shell, which facilitates counting. As stated before, incubation is best in an atmosphere nearly saturated with moisture, a condition more easily maintained than one of partial saturation.

The eggs used by the writers were obtained through the courtesy of Dr. D. F. Miller from the Departments' Fly Laboratory which is maintained in the interests of surgery. It was discovered that eggs coming from some cages were giving better hatches in the checks than were eggs from other cages. An investigation disclosed that a cage yielding eggs from which a high percentage hatch could be obtained from the checks, did so consistently throughout the life of the cage. The same was true of cages yielding eggs from which lower percentages of hatch were obtained from the checks. A subsequent investigation indicated that the poor hatches were due to a lack of fertilization.

Discussion.—The method which has been proposed permits the testing of a number of toxic materials, or dilutions of the same, on the eggs of an insect under similar conditions of the environment (parallel tests). Since each lot of eggs used comes from a thoroughly mixed stock secured from a number of females of the same species, it seems fair to assume that we are sampling a mixed population as regards individuals and a homogenous population as regards species. This being true, then the toxic effect of each material or dilution is being measured by the same biologic entity under the same conditions of the environment. Since it is possible to control, to a reasonable degree, such superficial variables as time, temperature, humidity, and light, the results obtained from one series can be fairly compared with those taken from another.

The disadvantages of spraying, as a means of applying toxic materials in such tests, are evident. By washing the unattached eggs in the toxic

material or insecticide, the entire surface of each egg is wet, and the possibilities of mechanical injury are reduced to a minimum.

Some toxic materials, such as nicotine, are credited with having the properties of fumigants as well as those of contact insecticides. The method discussed in this paper gives such materials every advantage.

To use eggs having short incubation periods which may be obtained in numbers at any season of the year with a minimum amount of equipment enables one to make a great many tests in a short period of time, and at a season when the activities of the laboratory will not conflict with those of the field.

HALOWAX AS AN OVICIDE

By E. P. Breakey and A. C. Miller, *Crop Protection Institute Investigators, The Ohio State University, Columbus, Ohio*[1]

The growing interest in the ovicidal properties of contact insecticides led to a consideration of the possibilities in Halowax, a chlorinated naphthalene product. The senior writer had learned that this material, when applied to the eggs of the red spider, *Tetranychus telarius* L., possessed ovicidal properties.[2] Accordingly, an attempt has been made to compare the ovicidal properties of chlorinated naphthalene with those of the various substances commonly employed as contact insecticides. Our studies have been made from the point of view of the economic entomologist, and because our work has been of an exploratory nature, we are fully aware of the incompleteness of our investigations.

Before data could be obtained from which to make such comparisons, it was necessary to develop a procedure whereby each toxic substance of known purity and concentration could be tested on the same biologic entity in an environment favorable to its life and development, i.e., the successful incubation of the eggs. In other words, sufficient control must be exercised over such superficial factors as light, temperature, humidity, age and condition of the eggs, strength and purity of the toxin, and routine procedure, that it would be reasonably certain the presence of the toxin alone accounted for any difference in the hatches of treated and untreated lots of eggs.

A search of the literature revealed that most of the studies made on the ovicidal properties of contact insecticides were of a qualitative nature, and none of the methods used were applicable to the problems at hand. Finally, a procedure for making the tests was evolved which is believed to be sound and practical. This method has been described in detail,[3] and is the method used in obtaining the data on which this paper is based.

[1]The authors wish to acknowledge their indebtedness to the Department of Zoology and Entomology for the use of equipment and accomodations in carrying on these studies.

[2]Jl. Econ. Ent. 27:393–398.

[3]See A Method for Comparing the Ovicidal Properties of Contact Insecticides. Jl. Econ. Ent. 28:353–358.

The eggs of the Angoumois grain moth, *Sitotroga cerealella* Olivier, and of the Blow fly, *Phormia regina* Meig., and to a lesser extent those of the Mediterranean flour moth, *Ephestia kuehniella* Zeller, have been used in these studies. As a matter of record, it might be mentioned that we used very nearly 80,000 eggs of the Angoumois grain moth, 100,000 eggs of the Blow fly, and 25,000 eggs of the Mediterranean flour moth. Not more than 5% of the eggs of the Angoumois grain moth had reached the pink stage at the time of applying the sprays, the remainder being about 48 hours old. These were incubated at room temperature, counts being made one week following the application of the sprays. Eggs of the Blow fly were treated within a few hours after they were laid, counts being made 24 hours following application of the toxins. These insects are so well known to entomologists in general that descriptions of their eggs are scarcely warranted.

The original intention was to determine the lethal concentrations of the various substances commonly employed as contact insecticides, when applied to the same eggs under the conditions stipulated above. It seemed that the goal in such a study was to determine those concentrations which would kill 100% of the eggs. Actually, as the studies progressed, it developed that more was learned from the data than the mere determination of these important points.

It has been necessary to adopt an arbitrary definition of what constitutes an ovicide. Unless the meaning of the word is ignored, the definition must be limited to those materials and concentrations which kill the eggs. It is true that some materials have demonstrated possibilities as larvacides. However, to kill the larva after it leaves the egg, even though the amniotic sac may still cling to it, is a post embryonic phenomenon and such eggs have been counted as having hatched.

Since it is impossible to obtain the same percentage of survival in all checks, all results have been reduced to *percent control*, using the method suggested by the Insecticide and Fungicide Board of the United States Bureau of Entomology. The *percent control* established for each concentration of toxin as indicated by the curve is, of course, approximate. The curves which have been drawn to illustrate the lethal effects of the various toxins represent, in reality, averages for *percents control* obtained for the different concentrations used.

Whenever possible, each toxic substance studied has been obtained in a state of known purity and concentration, and from these the various preparations and dilutions have been made, the diluent in each instance being tap water. It is evident that commercial preparations are, for the most part, unsuited to studies such as are being reported, since the unknowns present may affect the behavior of the toxin.

NICOTINE.—Perhaps the most widely used contact insecticide is nicotine, and the most common forms are basic nicotine 40% and nicotine sulphate 40%. In studying the effects of these materials, dilutions were made so that results could be computed on the basis of the actual nicotine present. Accordingly it was found that it takes very nearly one part nicotine of the sulphate form in 700 parts of the spray to kill 100% of the eggs of the Angoumois grain moth, while basic nicotine

was effective at the lower concentration of one part in 750. Note that the two materials changed place in the lower concentrations. This is probably due to the fact that nicotine is liberated from the sulphate over a longer period of time, the effect thus showing on an egg having an incubation period as long as that of the Angoumois grain moth.

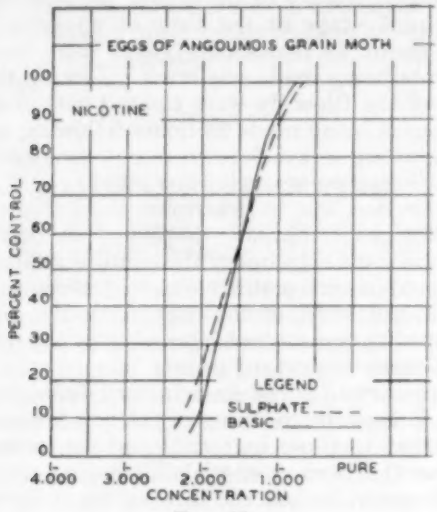


FIG.–42.

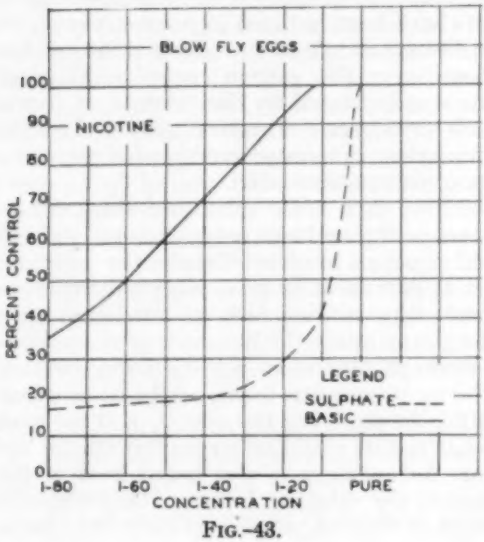


FIG.–43.

When these materials were tested on the eggs of the Blow fly, undiluted nicotine sulphate 40% failed to kill more than about 85% of the eggs. Basic nicotine made a better showing since one part in 12.5 parts of the spray killed 100% of the eggs. The two materials hold the same relative positions which they held with respect to their effects on the eggs of the Angoumois grain moth. Note the rapidity with which the effect of the sulphate form dropped away. Since the incubation period of this egg is short, the effect of the basic nicotine is relatively more noticeable.

PETROLEUM.—Mineral oil is another widely known contact insecticide. The oil used most frequently in these studies was of 80 viscosity and 90 plus sulphonation value. A simple emulsion of this oil had been prepared, using the same emulsifier as that used in Halowax emulsions. With such a preparation, it was hoped that effects of the oil might be separated from those of the Halowax. One part of the oil in 100 parts of the spray was sufficient to kill about 85% of the eggs of the Angoumois grain moth. The same was true when the eggs of the Mediterranean flour moth were used.

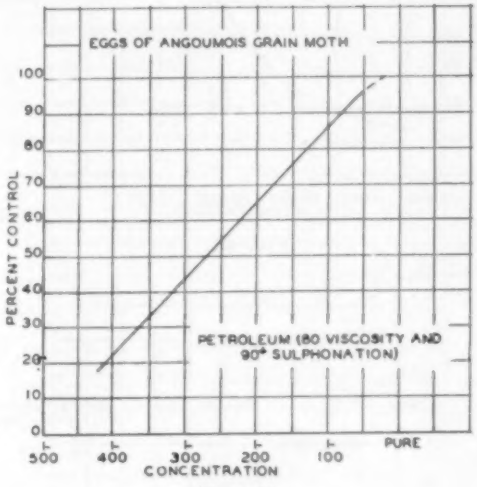


FIG.–44.

Some surprising results were obtained when the eggs of the Blow fly were subjected to treatment with mineral oils. Since the emulsion mentioned above apparently had no effect on the eggs of this insect at any dilution, various other oils were used. For example, it was found that as good hatches were secured from eggs placed in pure *Nujol* as were obtained from the checks. Since this oil is not miscible, the tests were repeated using the eggs in as dry condition as they could be obtained without danger of injury from dessication. Even though the oil apparently made satisfactory contact with the eggs, no effect could be detected from its presence. In order to use a well known miscible dormant

spray oil in the apparatus it was necessary to dilute it with an equal amount of water. This preparation also had no appreciable effect.

PYRETHRINS.—The pyrethrin sprays were prepared from a concentrate of Pyrethrum extract in alcohol assaying 3.375 grams of pyrethrins for each 100 cc. When the eggs of the Angoumois grain moth were treated with dilutions prepared from this stock, it was found that a concentration of one part pyrethrins in 5000 parts of the spray killed very nearly 95%.

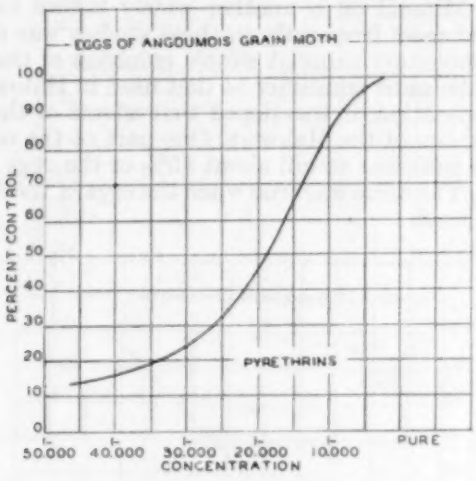


FIG.–45.

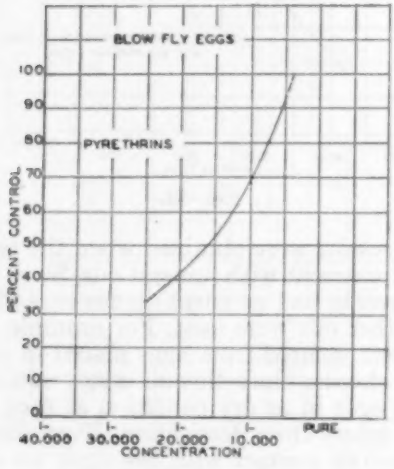


FIG.–46.

When pyrethrins were tested on the eggs of the Blow fly, it was found that a concentration of one part pyrethrins in 5000 parts of the spray killed better than 90% of the eggs. Note that the effect of the toxin falls away more rapidly when applied to the eggs of the Blow fly.

ROTENONE.—Rotenone sprays were prepared from an extract of Derris in pine oil, assaying 5 grams of rotenone for each 100 cc. Emulsions were made from this stock containing one part rotenone, 19 parts of pine oil, 5 parts of saponin, and 75 parts of water. Dilutions were made from these emulsions which gave the desired concentrations of rotenone. An attempt was also made to use rotenone as a colloidal suspension, preparing the suspensions from an extract of Derris in acetone with the aid of a protective colloid, tannic acid. The results obtained from the use of these suspensions confirmed, in general, those obtained from the use of the emulsions. However, since there appeared to be impurities present in the suspensions which might affect the behavior of the toxin, these results have not been used in preparing this paper.

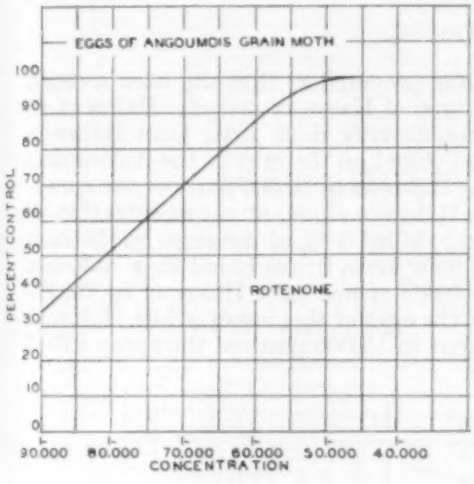


FIG.–47.

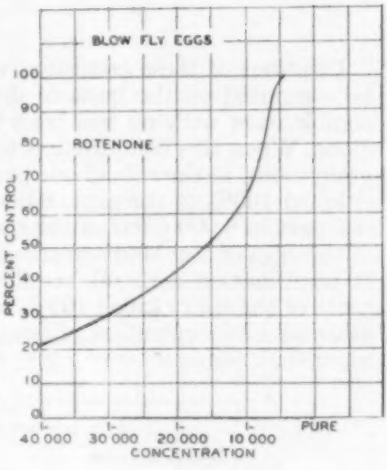


FIG.–48.

A concentration of one part rotenone in 50,000 parts of the spray killed more than 95% of the eggs of the Angoumois grain moth. It took a much higher concentration of rotenone to kill the eggs of the Blow fly, one part in 5,000 parts of the spray killing about 98%. Note that the effectiveness of this toxin also dropped away quite rapidly when applied to the eggs of the fly.

HALOWAX.—Two emulsions of Halowax were available for our studies, an emulsion of Halowax in combination with equal parts of mineral oil (80% viscosity and 90 plus sulphonation value), and an emulsion of Halowax alone. The same emulsifier was used in both of these preparations. It will be recalled that a simple emulsion of this mineral oil, pre-

pared with the same emulsifier, was available for studies on the effects of petroleum on insect eggs.

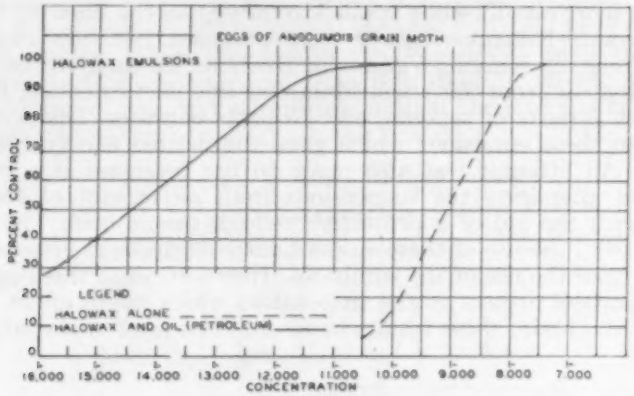


FIG.–49.

Dilutions of these emulsions were prepared so that the results could be computed on the basis of the actual Halowax present. Halowax in combination with oil has been consistently more toxic than Halowax alone. When this combination was tested on the eggs of the Angoumois grain moth, at the rate of one part Halowax in 10,500 parts of the spray, it killed 100% of the eggs, while Halowax alone, at a concentration of one part in 8,000 parts of the spray, killed 94% of the eggs. In the case of the eggs of the Mediterranean flour moth it was found that Halowax in combination with oil, on the basis of one part Halowax in 20,000 parts of the spray killed 100% of the eggs of this insect, while Halowax alone at a concentration of one part in 15,000 parts of the spray killed more than 90%.

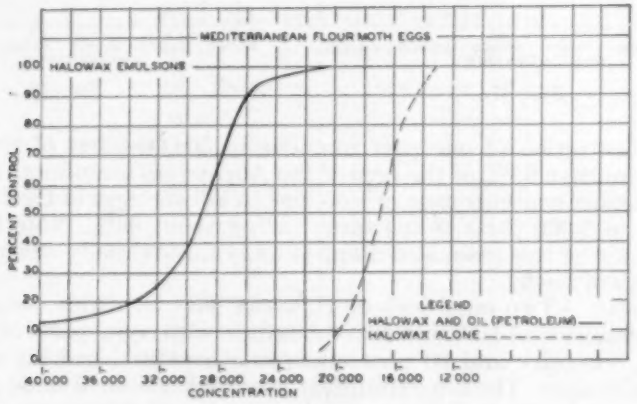


FIG.–50.

When dilutions of these emulsions were tested on the eggs of the Blow fly, Halowax maintained its relative position as an ovicide. Halowax in combination with oil, at the rate of one part of Halowax in 12,000 parts of the spray, killed 100% of the eggs of the fly, while Halowax alone at a concentration of one part in 6,000 killed 100%. It will be recalled that the effect of the mineral oil used in this combination, when prepared as a simple emulsion and tested on the eggs of the Blow fly, is apparently zero.

Of the various toxic substances used in these studies, Halowax has shown the least tendency to vary in its effects.

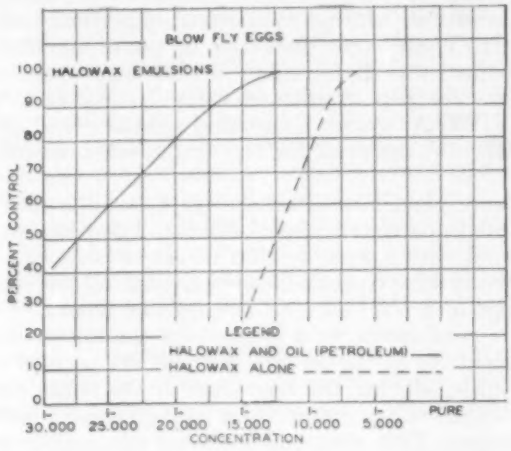


FIG.–51.

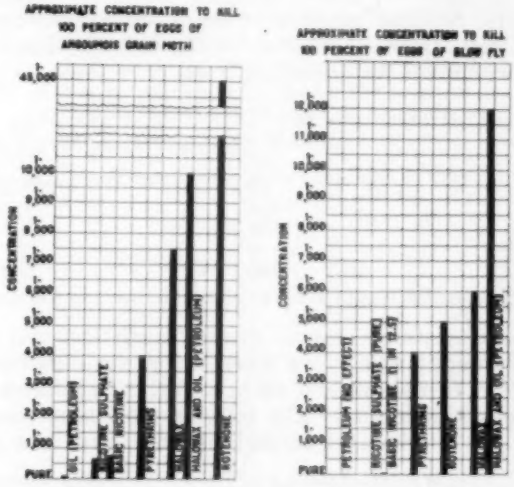


FIG.–52.

Saturday Morning, December 29, 1934

1934 NOTES ON BAITS FOR ORIENTAL FRUIT MOTH[1]

By S. W. FROST, *The Pennsylvania State College*

Forty different chemicals were tested for their efficiency in attracting the oriental fruit moth. Each test consisted of a series of ten baits placed in aluminum coated tin traps of about a gallon capacity. The attrahents were added at the rate of 1 cc. or 1 gram per trap, having previously filled the traps with a bait consisting of 1 part syrup and 20 parts water. Furfural and helmitol, being readily soluble in water, were added directly to the syrup solution. Methyl cinnamate, piperonal and thymol were difficult to mix. These were dissolved in warm mineral oil and then emulsified. Borneol was dissolved in alcohol before adding to the bait. All other chemicals were emulsified using 10 grams of the attrahent, 3 grams of No. 235 American Cyanamid spreader and 30 cc. of water. This made sufficient material for ten traps, when added to the syrup solution.

The traps were placed on alternate trees on alternate rows in a ten acre, interplanted peach and apple orchard. The position of each set of traps was altered once a week so that no set of baits was favored by its position. The tests were repeated four times during the summer covering a period, except in a few cases, of twenty-two weeks. Thus the action of the baits and variations were studied for the entire season including the cool periods of the spring and the hot and dry periods of the summer. Nothing was added during the operation of the traps except water, to compensate for slopping or evaporation; 385 gallons of water were added during the summer. This averaged less than one gallon per trap for the entire season. Heavy winds and rains occasionally caused traps to fall to the ground or spill the baits. In these cases the experiments were finished with the reduced number of traps. In presenting the figures in the table "Chemotropic Responses of the Oriental Fruit Moth" corrections have been made for discarded traps.

DETAILS OF THE OPERATION OF TRAPS

Month	Gallons of water added	Number of traps down[1]
May	105	3
June	45	21
July	125	2
August	102	14
September	8	1
Total	385	41

[1]Discontinued because the traps fell to the ground or because too much bait spilled.

The baits were examined twice a week until the end of July and thenceforth only once a week. The insects were strained from the traps, the baits returned to the original traps and these replaced on the trees for another week's collection. The catches of insects were taken to the laboratory for counts and further identification. An attempt was

[1]Publication authorized by the Director of the Pennsylvania Agricultural Experiment Station, December 10, 1934, as technical paper No. 671.

made to examine the surface of the baits twice a week and make counts of certain insects such as the codling moth, bud-moths and leaf-rollers. This procedure was not entirely satisfactory because frequent rains caused the insects to settle to the bottom of the traps. At the end of each test, the baits were discarded, the traps washed and new mixture placed in them.

The first five series of tests were conducted to obtain further information on the efficiency of different types of traps. Anethol was added to increase the catches. The results are summarized in the following table. Screens of ¼ and ½ inch mesh, over the tops of the traps, materially reduced the catch of oriental fruit moths. At the same time they failed to eliminate the objectionable Noctuidae and Euphoria. The catch of Noctuidae was reduced scarcely 60 per cent by the ¼ inch screen, while Euphoria was reduced scarcely 50 per cent by the ½ inch screens. Although previous records show that baffles increased somewhat the catch of oriental fruit moths, the tests conducted during 1934 were to the contrary. Baffles on the other hand increased the numbers of Euphoria and Noctuidae proportionally. Large enamel traps, with a diameter of 7¼ inches and a depth of 6 inches, caught only slightly more oriental fruit moths than number ten aluminum coated traps with a diameter of 6 inches and a depth of 7 inches. While the enamel traps are durable and will withstand the action of the baits longer than any other type of trap, except glass, they proved to be too heavy for practical purposes. Glass traps, of the Kerr type, were used for only eleven weeks. The average number of moths per trap compared favorably with that from other types of traps. It is questionable, however, whether these traps would continue to catch as many moths if the baits were not strained once a week.

Twelve of the chemicals were outstandingly attractive to the oriental fruit moth. Linalool, safrol, proply acetate, amyl acetate, anethol, terpinyl acetate and furfural were the best materials in order of attractiveness. Although linalool proved the most attractive, it is considerably more expensive than some of the other materials. Safrol, at $1.00 a pound, or 1/5 of a cent per trap, is decidedly within the range of practicability. Amyl acetate, at 1/10 a cent per trap, is cheaper but somewhat difficult to properly emulsify.

PROMISING ORIENTAL FRUIT MOTH ATTRAHENTS ARRANGED IN ORDER OF ATTRACTIVENESS

Attrahent	Number O. F. M. attracted	Cost per pound	Cost per trap
Linalool	7165	$4.75	.010
Safrol	6541	1.00	.002
Propyl acetate	5735	5.50	.012
Amyl acetate	5458	.50	.001
Anethol	5162	1.70	.004
Fennel seed oil	4983	1.65	.004
Terpinyl acetate	4798	3.50	.008
Furfural[1]	4699	1.40	.003

[1]Chemically pure material was used. Technical furfural can be purchased for $.60 a pound.

For the benefit of those who wish to study baits in more detail and those who may wish to try some of the attrahents, the following list of chemicals were used during 1934.[2]

[2]All chemicals, except those otherwise stated, were purchased from Eimer & Amend. 1— Eastman, 2— Givaudan-Delawanna, 3— Fisher, 4— Winthrop.

CHEMITROPIC RESPONSES OF THE ORIENTAL FRUIT MOTH

Attrahent	Test 1 May-June	Test 2 June-July	Test 3 July-August	Test 4 Aug.-Sept.	Totals
¼ inch screen, Anethol	197	2262	1392	139	3390
⅓ inch screen, Anethol	156	2756	1320	218	4450
Baffles, Anethol	282	4088	1164	163	5697
Enamel traps, Anethol	340	4217	948	124	5629
1 quart glass, Anethol	——	——	2057	196	2253[1]
Syrup 1–20	74	1356	830	32	2292
Methyl allephenol	168	3166	1568	260	5162
Methyl phenol	14	112	302	52	480
Methyl phenol ester	50	821	658	58	1587
Methyl isopropylphenol	291	569	427	273	1560
Methyl cinnamate	66	2243	310	135	2754
Ethyl cinnamate	131	1632	2249	353	4365
Propyl acetate	121	2793	2443	378	5735
Terpinyl, acetate	832	2396	1284	322	4834
Geranyl acetate	100	691	239	101	1131
Amyl acetate	119	3559	1568	212	5458
Amyl valeriate	200	1084	379	141	1804
Amyl formate	382	611	368	149	1510
Amyl salicylate	215	1483	500	199	2397
Bensyl aldehyde	125	788	485	95	1493
Cinnamic aldehyde	71	742	704	380	1897
Formaldehyde	147	951	1527	885	3510
Bromostyrene	137	566	467	268	1438
Pinene	343	2747	1030	263	4383
Citrene	206	1800	574	197	2777
Borneol	114	1072	1914	196	3296
Piperonal	99	2210	1050	832	4191
Citral	143	1748	1705	273	3869
Furfural	235	1772	2467	235	4709
Safrol	334	2549	2324	1334	6541
Eucalyptol	410	1198	523	213	2344
Terpinol	212	2293	834	179	3536
Helmitol	331	1424	383	140	2278
Linalool	389	4828	1365	583	7165
Geraniol	121	2152	466	47	2786
Almond oil	270	1717	1125	51	3163
Anise oil	408	2307	1587	158	4460
Pennel seed oil	430	1957	2475	121	4983
Rose geranium oil	158	539	1094	52	1843
Lemon oil	211	1330	382	48	1971
Orange oil	301	1395	344	136	2176
Pine oil	——	——	81	24	105[1]
Eugenol	——	——	451	277	728[1]
Terpentine	——	——	218	73	291[1]
Linalool without syrup	——	——	24	3	27[1]
Totals	8915	73924	45605	10568	139012

[1]Duration 11 weeks, all others 22 weeks.

Methyl allephenol, Anethol N. F. $C_{10}H_{12}O$
Methyl phenol, Cresol meta technical——C_7H_8O
Methyl phenol, ester anisol C. P. C_7H_8O
Methyl isopropylphenol, Thymol U. S. P. $C_{10}H_{14}O$
Methyl cinnamate $C_{10}H_{10}O_2$
Ethyl cinnamate $C_{11}H_{12}O_2$
Propyl acetate, C. P. normal $C_5H_{12}O_2$
Terpinyl acetate $C_{12}H_{21}O_2$
1 Geranyl acetate, tech. from Eucalyptus oil $C_{12}H_{20}O_2$
Amyl acetate, solvent tech. $C_7H_{14}O_2$
Amyl valeriate $C_{10}H_{20}O_2$
Amyl formate, pure $C_6H_{12}O_2$
Amyl salicylate $C_{12}H_{16}O_3$
Benzyl aldehyde C_7H_6O
Cinnamic aldehyde C_9H_8O
Formaldehyde C H_2O
Bromostryene C_8H_7Br.
Pinene, pure $C_{10}H_{16}$
2 Citrene $C_{10}H_{16}$
3 Borneol $C_{10}H_{18}O$
Piperonal, Heliotropine C_8H_6O

Citral $C_{10}H_{16}O$
Furfural, C. P $C_5H_4O_2$
Safrol $C_{10}H_{10}O_2$
Eucalyptol, U.S.P $C_{10}H_{18}O$
Terpinol, pure $C_{10}H_{18}O$
Linalool $C_{10}H_{18}O$
Geraniol $C_{10}H_{18}O$
Eugenol, U.S.P $C_{10}H_{12}O_2$
4 Helmitol Hexamethylenamineanhydromethylene citrate (a brand of Citramin) ———$C_7H_8O_7$ ($C H_2$) N_4
Almond oil, true bitter
Anise seed oil
Fennel seed oil
Rose geranium oil
Lemon oil
Orange oil, sweet
Pine oil, technical
Terpentine, commercial.

CONCLUSIONS.—Screens cut down the catch of oriental fruit moth considerably and do not reduce the Noctuidae and Euphoria sufficiently. Baffles are apparently of little value. Number ten tin traps, coated with aluminum paint, appear to be the best type of trap. Safrol is the most satisfactory material to be added to a 1–20 syrup solution to attract oriental fruit moths.

VARIATIONS IN SEASONAL PREVALENCE OF ORIENTAL FRUIT MOTH ADULTS IN PEACH AND QUINCE ORCHARDS

By R. B. NEISWANDER, *Ohio Agricultural Experiment Station*

Fruit moth bait traps have been employed in an orchard in Lorain County, Ohio, each season since 1930. Sixty traps, similar to the type designed by W. P. Yetter, Jr.[1], have been used. They consisted of wide-mouth, Kerr-type fruit jars covered with ¼-inch mesh hardware cloth and were provided with wire-bail supports.

The bait was prepared each season by mixing 3 quarts of refiner's syrup with enough water to make 10 gallons. The traps were filled with this solution to approximately 1 inch from the top. They were then hung well up in the trees; they were placed in alternate trees in alternate rows.

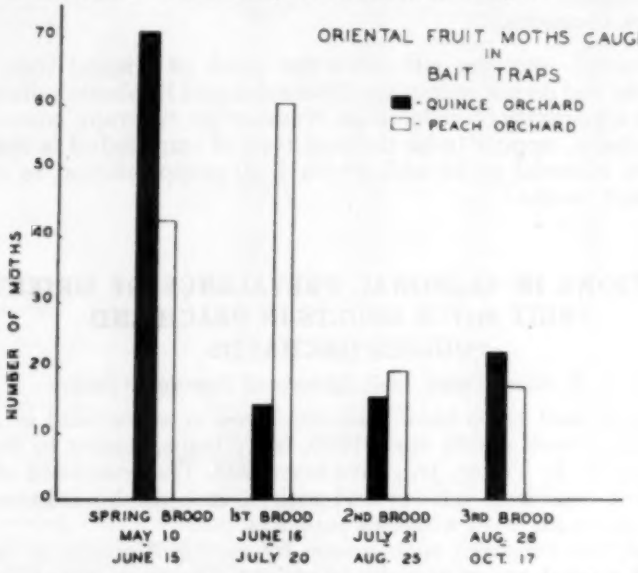
During the seasons of 1930 and 1931, no additional attrahent was added to the bait, but, beginning with 1932, a small quantity of ethyl cinnamate was added to each trap, the amount used in 1934 being ¼ cc. per trap. The records obtained during these three seasons have been quite similar, and the record for 1934 is almost a duplicate of that for 1932. During each of the three seasons the greatest weekly catch occurred during the fore part of July.

During the season of 1934 another series of 32 traps was employed in a block of 64 quince trees in Ottawa County. The same type of trap

[1]Jour. Econ. Ent., Vol. 23, pp. 85–91.

and the same bait were used as were employed in the peach orchard. The traps were placed in operation in both orchards on May 3rd and were refilled in the same manner approximately every fourth week. Only half of the traps in each orchard were refilled during the same week in order to counteract a possible influence from renewing the bait on the relative numbers of moths caught. The traps in the quince orchard were placed in alternate trees in each row. All traps were in operation 162 days.

The total catch per trap was 139.3 moths in the peach orchard and 123.7 moths in the quince orchard. Since a trap was placed in every fourth tree in the peach orchard, as compared with a trap in every other tree in the quince orchard, the difference in total catch may be due in part to a difference in the competition between traps.



The number of moths of the various broods caught in the two blocks s shown graphically in the accompanying figure. The total catch per trap from May 10 to June 15, designated in the figure as Spring-Brood Moths, was 71.1 in the quince block and 42.6 in the peach orchard. Usually, quince fruits are more heavily infested than peaches; moreover, it has been shown that more moths hibernate on quince trees that have borne a crop than on bearing peach trees. Since first-brood larvae feed almost entirely on peach twigs, it seems probable that the spring-brood moths which emerge elsewhere than in peach orchards migrate to peach trees for oviposition. The size of the moth catch in the quince block indicates that, if this migration occurs, moths were caught soon after emergence and hence before oviposition.

The average catch per trap of first and second brood moths in the peach orchard was, respectively, 60.2 and 19.4 and in the quince orchard

14.4 and 15.6. It is noteworthy that more than four times as many first-brood moths were caught in the peach orchard as in the quince block. This substantiates the statement mentioned previously that first-brood larvae feed almost entirely on peach twigs. The numbers of second-brood moths caught in the two blocks are more nearly equal; this indicates that the larvae had begun feeding in fruit.

The number of moths caught per trap from August 26 to October 17 was 17.1 in the peach orchard and 22.5 in the quince block. This again corresponds to the known traits of the fruit moth, in that quinces are more heavily infested than peaches and that larvae feed chiefly in fruit at that season of the year.

The largest weekly catch in the peach orchard, 34.3 per trap, occurred on July 6 when most larvae were feeding in twigs where they were exposed to parasites and when parasite activity was at its height. In fact, the drop in the population in the peach orchard following this period was no doubt due to parasite activity. The largest weekly catch in the quince orchard, 25.5 per trap, occurred on May 23 when the hibernating brood was being caught. The population in quinces, therefore, became greatest in the fall of the year, and the larvae went into hibernation relatively free from parasites.

This comparison of the seasonal populations in quince and peach orchards may be summarized by saying that moth prevalence tends to shift from quince to peach in the early part of the season and from peach to quince as the fruit of the latter becomes suitable food material. Consequently, more larvae go into hibernation on or near quince trees. This may be interpreted to mean either that the attractiveness of quince foliage for oviposition changes during the summer or that larval mortality on quince trees is very high during the early part of the summer.

NOTES ON THE BIOLOGY AND THE DEVELOPMENTAL STAGES OF *GLYPTA RUFISCUTELLARIS* CRESS., (ICHNEUMONIDAE, HYMENOPTERA), A LARVAL PARASITE OF THE ORIENTAL FRUIT MOTH

By B. ELWOOD MONTGOMERY, *Department of Entomology, Purdue University*[1]

Glypta rufiscutellaris Cress. is one of the native parasites of stemboring lepidopterous larvae that have accepted the oriental fruit moth, *Grapholitha molesta* (Busck), as a host. In some localities it appears to be the predominant parasite of this species.

In parasite work, especially in projects in which infested host larvae are collected to secure parasites for colonization or rearing, it is important that all of the common parasites of the particular host be recognized in whatever stage found. This study was undertaken at the suggestion and under the direction of Dr. H. W. Allen, in order that drawings and

[1]The author was Field Assistant, Bureau of Entomology, (a part of the present Bureau of Entomology and Plant Quarantine.) United States Department of Agriculture, Moorestown, N. J., when this study was made.

descriptions of the various stages of this parasite might be secured. The limited observations on the life history of the parasite which could be made in the course of the study are included.

The study was made at the Moorestown N. J., Laboratory of the Bureau of Entomology, (a part of the present Bureau of Entomology and Plant Quarantine.) during August 1930. Adult parasites for the work were obtained from field collections of peach twigs infested with oriental fruit moth larvae. This material was collected for another purpose and came from many localities in states east of the Mississippi River. As the number of adult parasites emerging at any one time was small, males and females from widely separated localities were frequently mated. The adults used in the oviposition cages for this study emerged from material collected at Painesville and Amherst, Ohio, North Girard, Pa., Ransomville, N. Y., and Pennington, N. J.

In order that host larvae of known age might be available, a large number of both sexes of *G. molesta* were maintained in small wire cages and fresh pear foliage upon which eggs might be deposited was introduced into these cages daily. When the eggs were about ready to hatch, the pear leaves to which they were attached were placed in contact with freshly gathered, tender tips of peach twigs, one twig for every two eggs. Upon hatching, the larvae entered these twigs; usually two larvae entered each twig. The twigs were exposed to adult parasites for 24 hours. Each lot was then placed in a jelly glass containing an apple and a narrow strip of corrugated paper. The larvae could enter the apple to complete their development when the peach twigs were consumed or became unfit for further feeding. When development was complete the larvae entered the tunnels in the corrugated paper to spin cocoons.

Adult parasites were taken from emergence cages each morning, and those to be used for this study were placed directly in oviposition cages. If available in equal numbers, one female and one male were placed in each cage, in some cases two females and one male were placed in a cage, and in a few cases two or three females not previously fertilized were placed in a cage alone. Each cage was supplied with a shallow dish containing a honey solution and a small piece of sponge, which were renewed daily.

Peach twigs containing host larvae were placed in the cages in such a manner that the parasites had access to all parts. Each lot of twigs contained the larvae surviving from the hatch of 20 or 25 eggs. Fresh host material was introduced into each cage daily, as long as the female parasite lived or until the study was concluded.

Female parasites were frequently observed at work on twigs containing host larvae, especially just after fresh material had been introduced into the cages. They ran up and down the twigs with quick, "nervous" movements, vibrating the antennae rapidly, and stopping occasionally to insert the ovipositor into the twig. After the ovipositor had been inserted for its entire length the parasite turned and twisted about for some seconds as if probing in the burrow to find the host larvae. Apparently the ovipositor was inserted through an opening in the twig made

by the host larva, but it was not determined if this were always the case. Although the activity of the parasite was most intense just after fresh material had been introduced, it did not cease entirely even if this material were allowed to remain until the second day.

The different larval instars of the parasite were determined by dissections of a number of parasitized host larvae at different times after parasitization. No dissections were made later than the twenty-first day after parasitization. Although the host would normally advance beyond the larval stage in this time under the conditions of the study, second and third instar larvae were dissected from host larvae on the twentieth day and no parasitized host larvae gave any indication of pupation.

Host larvae ranging in age from 1 to 4 days at the time of introduction into the oviposition cages were used. The degree of parasitization obtained appeared to depend more upon the age of the host larvae than upon any other factor. Larvae 1 day old when exposed to parasites (in oviposition cages approximately 24 hours, beginning approximately 24 hours after hatching) showed 80 per cent parasitization, those 2 days old 53 per cent, those 3 days old 38 per cent, and those 4 days old only 16 per cent.

TABLE 1. AGE OF HOST LARVAE AT THE TIME OF OVIPOSITION AND THE DEGREE OF PARASITIZATION OBTAINED

Age of larvae (days)	Number of larvae dissected	Number found parasitized	Percentage of parasitization
1	25	20	80
2	39	21	53
3	13	5	38
4	31	5	16

No parasite larvae were found before the sixth day after oviposition and no eggs were found after that length of time, but the different larval instars showed considerable overlapping. First-instar larvae were found from the sixth to the fifteenth day, but second and third instar larvae were found as early as the twelfth and thirteenth days, respectively, and each as late as the twentieth day. Fourth instar or mature larvae were found in the host from the nineteenth to the twenty-first day and in the cocoon as early as the twentieth day. The percentage of the number of larvae of each instar observed which were found at any particular time after oviposition is indicated in the accompanying table (Table 2).

TABLE 2. NUMBER OF DAYS AFTER OVIPOSITION WHEN EACH INSTAR OF THE PARASITE WAS FOUND

Instar	Total number observed	Percentage of total number of each instar observed in indicated number of days from oviposition to dissection															
		6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
First	13	8	38	31	–	15	—	—	—	—	8	—	—	—	—	—	—
Second	9	–	—	—	–	—	—	22	45	—	11	—	11	—	—	11	—
Third	9	–	—	—	–	—	—	—	34	11	—	33	—	—	11	11	—
Fourth	17	–	—	—	–	—	—	—	—	—	—	—	—	—	12	41	47
(in host)	9	–	—	—	–	—	—	—	—	—	—	—	—	—	22	56	22
(spinning cocoon)	2	–	—	—	–	—	—	—	—	—	—	—	—	—	—	50	50
(in cocoon)	6	–	—	—	–	—	—	—	—	—	—	—	—	—	—	17	83

Superparasitism was observed only once—a host larva dissected on the sixth day after oviposition contained an egg and a first-instar larva.

Parasite larvae were found in a few host larvae which had been exposed to only unfertilized female parasites.

The parasite appeared to be free in the body cavity of the host and the internal organs of the latter were crowded against the body wall as the parasite grew, until the fourth instar was reached, when the tissues of the host, except the tracheae and the body wall, were consumed. At

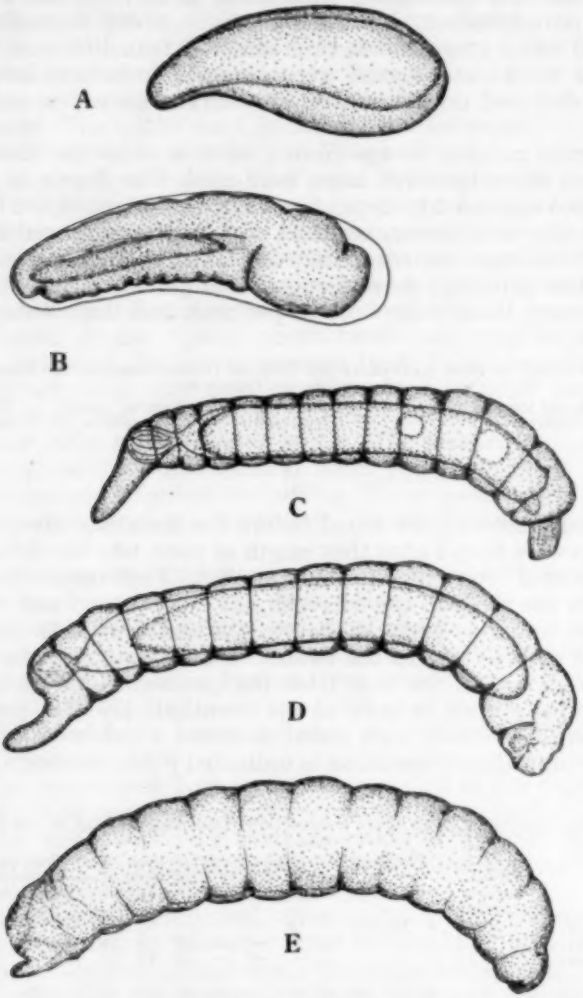


FIG. 53.—Eggs and larvae of *Glypta rufiscutellaris* Cress. A. Egg dissected from female (150X). B. Egg found in host larva on the second day after oviposition (150X). C. First-instar larva (60X). D. Second-instar larva (40X). E. Third-instar larva (27X).

this stage the parasite filled the skin of the host to distention. Finally the head of the parasite appeared through the body wall of the host on the dorsal aspect of the last segments, and the old host skin was worked off by vigorous wriggling.

The freshly deposited egg was not seen, but eggs apparently fully developed (Fig. 53, A) were dissected from a fertile female. These were pearly white in color, about 0.35 mm in length and 0.15 mm in greatest width. In outline the shape was obovate with one side very deeply concave near the smaller, or caudal, end. An egg dissected from a host larva on the second day after oviposition (Fig. 53, B) was somewhat more elongate, being about 0.44 mm in length and only 0.125 mm in greatest width. It contained a well-developed embryo.

The first-instar larva (Fig. 53, C) is almost cylindrical, tapering somewhat from the third or fourth segment to the caudal end of the body. It is about 1.4–1.6 mm long and 0.18–0.24 mm in greatest width. The head is a chitinized capsule about one-third as broad as the segment to which it is attached and 0.13 mm long. It is yellow, becoming darker toward the mouthparts, which are brown. The body is translucent, with a few blotches of white. The digestive tract can be seen rather distinctly. The anal process is round in cross-section, tapers considerably, and is acutely rounded at the apex. There is no constriction at the base and it appears to be a continuation of the body, bent caudo-ventrad. It is about as long as the three posterior body segments combined.

The second-instar larva (Fig. 53, D) is cylindrical on anterior half, slightly tapering on posterior half. It is about 2.4 mm long and 0.3 mm wide. The head is not distinct from the first body segment and does not differ from the remainder of the body in color. It appears to have lost the heavy chitinization of the first-instar larval head. The body is translucent with considerable white tissue visible through the body wall, especially in the second and the last three or four segments. The digestive tract is yellow and is quite distinctly visible through the surrounding tissues. The anal process is cylindrical, with a diameter at the base only about one-half that of the body. In lateral view it is curved slightly dorsad from the curve of the ventral margin of the body.

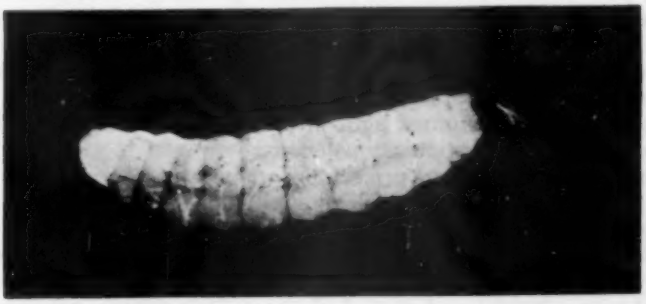


FIG. 54.—Fourth-instar larva within skin of host. The tissues of the latter, except the tracheae and the body wall, have been consumed.

It is rounded at the apex and is about equal in length to the two posterior segments combined.

The third-instar larva (Fig. 53, E) is cylindrical except for a slight tapering in the posterior third of the body. It is about 3.5–3.7 mm long and 0.5–0.7 mm wide. The head is somewhat more distinctly separated from the first body segment than in the second instar; it appears not to be heavily chitinized. The head and the two caudal segments of the body are translucent; the remainder of the body is white, but the digestive tract, although not distinctly visible through the surrounding tissue, gives a yellowish tinge to the body. The anal process is a short rounded projection, about as long as the last segment of the body, and with a diameter of about one-fourth that of the body. Its ventral margin, from lateral view, practically continues the curve of the ventral margin of the body.

The fourth-instar larva (Fig. 54), at the time it leaves the host, is 5 to 6 mm long and about 1.5–1.75 mm wide. The head is very narrow and is slightly retracted into the following segment. Pupal structures, as the eyes and mouthparts, appear to be forming beneath the surface and these give the head the appearance of being lightly chitinized. The body is white with a yellow or pink tinge in some specimens. The body segmentation is quite marked, especially in dorsal view. Only a trace of the anal process can be seen.

LARVICIDAL EFFICIENCY OF CERTAIN SPRAY COMBINATIONS AGAINST THE FRUIT TREE LEAFROLLER[1]

By P. J. CHAPMAN and R. W. DEAN, *New York State Agricultural Experiment Station, Geneva, N. Y.*

In combating the extreme infestations of the fruit tree leafroller, *Cacoecia argyrospila* Walker, which have appeared at one time or another in almost every deciduous fruit district of the United States and Canada, poor results have been obtained generally with lead arsenate and other larvicides. Lubricating oil emulsions containing from 6 to 8 per cent oil have been found to be efficient ovicides however, and their use as dormant sprays has become the standard recommendation when coping with severe infestations of this pest. Lead arsenate is usually suggested for use only against light infestations or to supplement the oil treatment when heavy populations occur.

This paper describes some preliminary experiments conducted in 1934 in which a rather high control efficiency has been obtained with certain spray combinations directed against the larvae. The experimental block included 68 McIntosh and Baldwin apple trees in the center of a heavily infested orchard located near Fishkill, N. Y. The trees are 20 years old with a height and spread of about 21 and 24 feet, respectively.

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The benefits attributed to the spray mixtures tested have apparently been derived from two treatments: one applied May 5 just before blossoming and the other directly after, on May 14. The leafroller eggs hatched between May 5 and 9. All spraying was done from the ground, using a spray-gun, and the material was applied under a pressure of from 400 to 450 pounds. An average of 17 gallons of spray per tree was applied May 5 and 21 gallons on May 14.

Some of the spray combinations tested are given in Table 1. A fungicide has been included in all formulae for protection against apple scab which requires attention at this period of growth in this area. The choice of the particular fungicide was determined by its supposed compatibility with the other ingredients of spray mixture or, in the case of derris and

TABLE 1. THE LARVICIDAL EFFICIENCY OF SOME SPRAY FORMULAE IN 1934 TESTS AGAINST *C. argyrospila*

Plat number	Spray formula (Amounts added to 100 gallons of water)		Mature fruits injured, per cent	Number trees examined	Average number fruits per tree	Theoretical average reduction in yield, per cent[7]	Control efficiency, per cent, based on		Remarks
							Mature fruits only	Mature fruits plus loss in yield	
1	Calcium arsenate	6 lbs.							
	Lime-sulfur	2 gals.	28.1	5	962	54.4	57.0	32.7	
	Ortho spreader[1]	1 lb.							
2	Lead arsenate	6 lbs.							
	Lime-sulfur	2 gals.	18.1	7	1,468	30.4	72.3	57.1	
	Ortho spreader[1]	1 lb.							
3	Lead arsenate	6 lbs.	6.6	4	2,107	0.0	90.0	90.0	Moderate russeting on some fruits
	Orthol K oil[2]	1 gal.							
	Coposil	3 lbs.							
4	Lead arsenate	6 lbs.	4.0	6		0.0	93.8	93.8	Moderate russeting on some fruits
	Orthol K oil[2]	1 gal.							
	Nicotine sulfate	1 qt.							
	Coposil[3]	3 lbs.							
5	Nicotine sulfate	1 qt.							
	Ammonium sulfo soap	1 qt.	17.6	4	1,051	50.2	73.0	41.0	
	Flotation sulfur[4]	5 lbs.							
6	Black Leaf 155[5]	10 lbs.	22.4	4	1,104	47.6	65.7	43.6	
	Flotation sulfur	5 lbs.							
7	Nicotine sulfate	1 qt.							
	Kolofog[6]	8 lbs.	14.5	4	1,828	13.3	68.6	74.2	
x	Check (for plats 1 to 6 inclusive)		65.4	6	964	54.3	—	—	
x	Check (for Plat 7)		46.2	2					

[1]Said to contain calcium caseinate and bentonite. A product of the California Spray-Chemical Corporation, New York City.

[2]A neutral "summer" oil emulsion. Contains a petroleum oil of a viscosity of approximately 70 seconds. California Spray-Chemical Corporation.

[3]Copper ammonium silicate. Powdered form. Three pounds of hydrated lime were added to all spray formulae when Coposil was used in this experiment. California Spray-Chemical Corporation.

[4]A fungicide containing about 85 per cent sulfur. The dry-wettable form. Koppers Products Co., Pittsburg, Pa.

[5]A powdered fixed nicotine product. Prepared from nicotine sulfate, bentonite, ammonium sulfo soap, and copper sulfate. Contains 7.5 per cent nicotine. Manufactured by Tobacco By-Products and Chemical Corporation, Louisville, Ky.

[6]A fungicide composed of sulfur (30 to 40 per cent) and bentonite which have been fused and reground. Product of the Niagara Sprayer and Chemical Corporation, Middleport, N. Y.

[7]The 10 trees in Plats 3 and 4 appeared to produce a normal crop and their average yield has been used as a basis for calculating yield reductions in the other plats.

nicotine, on reaction—a neutral or near neutral medium being sought. Several spray combinations in addition to those given in Table 1 were tested in a limited way in 1934, with the following general results: ground derris root 5 pounds (containing 5 per cent rotenone) and flotation sulfur 5 pounds in 100 gallons water appeared to effect little or no control; synthetic cryolite 5 pounds, Orthol K oil 1 gallon, Coposil 3 pounds in 100 gallons water gave poor results, altho causing some reduction in the population; nicotine sulfate 1 quart, Orthol K oil 1 gallon, and Coposil 3 pounds in 100 gallons of water gave results similar to formulae Nos. 5 and 6 of Table 1.

The efficiency of the several treatments is expressed on the basis of the fruits which sustained relatively minor injuries, as shown by healed scars at harvest time, and on those which were fatally injured (either by the insect or treatment) as is indicated from a departure from the "normal" yield. No satisfactory method was found of determining the amount of damage in the second category thru direct means. Yield data gives only an approximate record. However, when this loss amounts to 50 per cent or more of the crop as in the present instance (Tables 1 and 2), any measure of fruit injury is incomplete that disregards the loss arising from the destruction of potential fruits occurring before, during, and for several weeks after blossoming.

TABLE 2. RELATIONSHIP BETWEEN INTENSITY OF INFESTATION AND THE NUMBER OF FRUITS ATTAINING MATURITY[1]

Tree number	Location	Dimensions of tree in feet		Total number fruits	Total fruits infested	Remarks
		Height	Spread			
1.....	In center of the infestation	26	31	1,781	1,483	Most injured fruit badly deformed
2.....	In center of the infestation	22	27	1,383	1,050	Most injured fruit badly deformed
3.....	400 yards distant	24	28	5,295	383	Most injured fruit showed only moderate or light feeding
4.....	400 yards distant	22	27	4,843	520	Most injured fruit showed only moderate or light feeding

[1]These data approximate the conditions existing in two parts of the orchard at Fishkill, N. Y., where the only known variable was the intensity of infestation. McIntosh trees outside the exp erimental area

DISCUSSION OF RESULTS.—The data obtained in these preliminary experiments suggest that newly hatched *C. argyrospila* larvae are readily poisoned with lead arsenate, but that in actual control operations the principal problem is to obtain and maintain adequate coverage of the surfaces where the larvae feed thruout the egg-hatching period. Presumably, the coverage properties needed are of the type supplied by the summer oil emulsion used in these tests rather than by the casein or similar "spreaders." Available evidence indicates that the oil itself contributed no appreciable insecticidal action. The egg masses on trees in these plats hatched normally, and altho no plat received the summer oil alone, the results with it in combination with nicotine sulfate and cryolite suggests that this oil had little if any larvicidal value.

The problem in this area is complicated by the necessity of having to include a fungicide in leafroller spray formulae. Thus, the summer oil-lead arsenate-Coposil formulae of Table 1 are probably unsuited for recommendation to orchardists in their present form because some fruit

russeting occurred— attributable, so it appears, to the copper in the fungicide.

The partial control obtained with nicotine in various combinations appears to warrant its further consideration.

The duration of egg-hatching and the time of its occurrence with respect to host development are apparently subject to important seasonal, varietal and regional variations. Hatching commonly takes place on apples during the week or 10 days preceding blossoming. In relation to control practices this means that the primary leafroller treatments are usually the preblossom applications. In coping with heavy populations, however, it appears advisable to determine the time and number of sprays required more on a knowledge of the actual occurrence of hatching rather than by some arbitrary stage-of-growth schedule.

THE BIOLOGY OF THE APPLE APHIDS IN RELATION TO FALL SPRAYING[1]

By T. Walter Reed, *New York Agricultural Experiment Station, Geneva, N. Y.*

In the Western New York fruit belt, the apple aphids are second only to the codling moth in importance as pests of apple. The standard control measure in this area consists of using 1 pt. of nicotine sulfate in the delayed dormant spray. When applied under ideal conditions this treatment results in excellent control, but growers have experienced difficulty with high winds, cold weather and with completing the coverage of large acreages because of the shortness of the period that the spray is effective.

In 1929 a study of the habits of the apple aphids during the fall months was begun in an effort to determine whether or not it was feasible to use control measures during this period. Three species of aphids are found on apple trees during the fall months; these are the rosy apple aphid, *Anuraphis roseus* Baker; the green apple aphid, *Aphis pomi* De Geer; and the apple grain aphid, *Rhopalosiphum prunifoliae* Fitch. *A. roseus* and *R. prunifoliae* return from summer host plants in the form of winged fall migrants while *A. pomi* exists on the apple during the entire season.

Biological Observations

Anuraphis roseus. The winged viviparous females begin to appear on the apple trees from about Sept. 20 to October 1 and continue to arrive until the middle of October. They settle on the leaves where they feed and in a few days give rise to a generation of wingless oviparous females. Each winged female gives birth to only a few individuals which are deposited singly on the under side of the leaves. On younger trees (10 to 30 years old) the foliage on the fruit spurs along the larger branches and toward the center of the trees is preferred. With older trees on which there is little foliage near the center the aphids are found on the fruit

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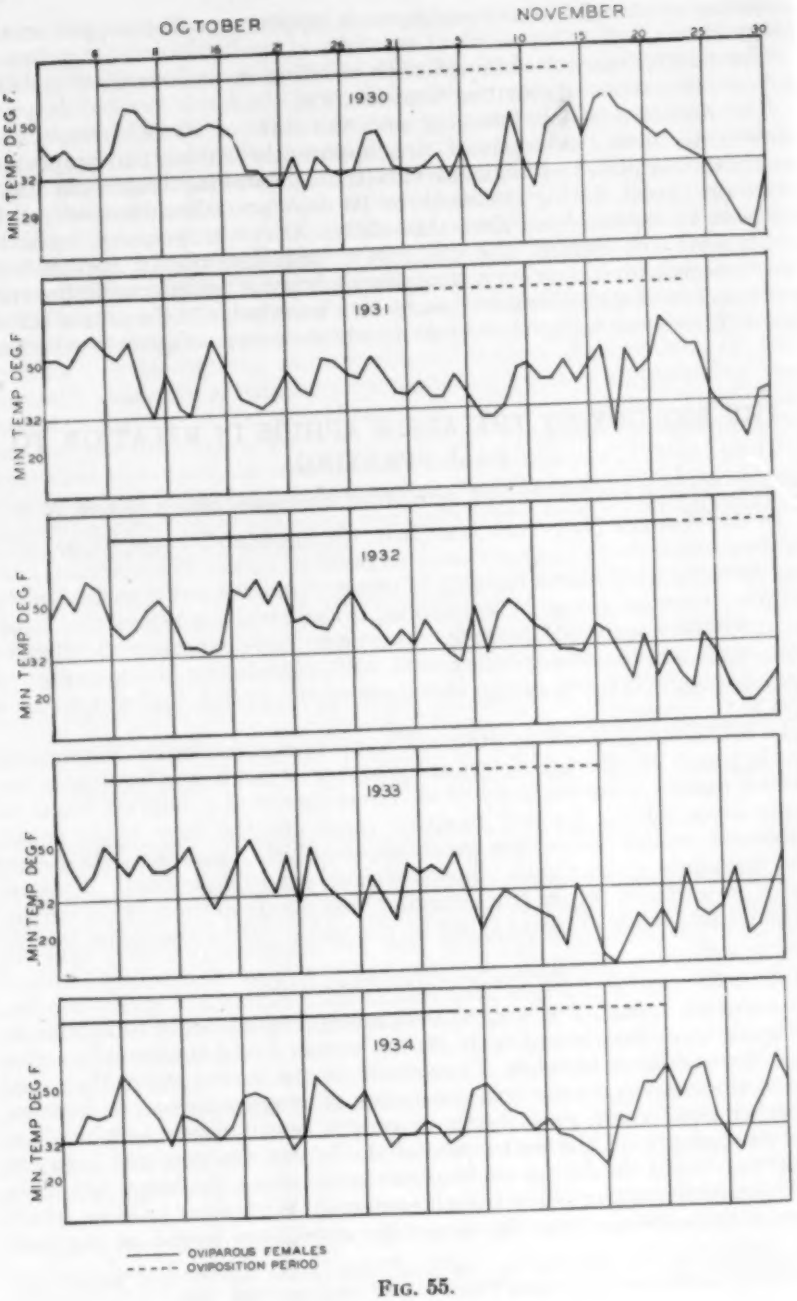
OCTOBER
NOVEMBER
1930
1931
1932
1933
1934
MIN TEMP DEG F.
50
32
20
OVIPAROUS FEMALES
OVIPOSITION PERIOD

FIG. 55.

spurs near the outside of the tree but seldom on the foliage of the growing terminals. The oviparous females were not observed to become numerous; 88 per 100 leaves being the maximum number observed, 20 to 30 per 100 leaves was the population usually occurring.

These young are a pale lemon yellow when first born, later turning darker, being an orange color when mature. The antennae are long, reaching to the base of the cornicles, eyes black, cornicle long, reaching as far to the rear as the tip of the abdomen. The body is plump and rounded.

The oviparous females mature late in October and early in November and mate with the winged males that return at that time. Copulation was observed as early as two weeks before oviposition began while the females were still feeding, but it was most common during the period when the females were leaving the leaves for the branches prior to egg laying.

In general no eggs were laid until after some freezing weather had occurred. (Fig. 55) The low temperatures usually killed most of the leaf but small green areas along the midvein always remained and the immature aphids would feed there. These frosted leaves soon began to drop but defoliation was not completed until about 2 weeks later. So when some of the immature females drop to the ground with the foliage this loss is apparently of no great importance in the winter survival of the species. The females can withstand considerable cold weather and resume oviposition when the temperature reaches about 40 degrees F. or above. During 1933, for example, they withstood a temperature of 20 degrees F. and resumed egg laying when the temperature became favorable; after a temperature of 10 degrees F. on November 15, females brought into a warm room began to move about, but on November 16 when the temperature dropped to 7 degrees F. all aphids succumbed. The aphids were killed before many eggs had been laid and as a result severe infestations of rosy aphis in 1934 were rare.

The eggs are laid on the limbs, generally on the lower side, not far from the leaves on which the females matured. They are always well hidden, occurring under rough bark, in cracks, pruning scars, etc. The eggs are oval and slightly kidney shaped, light yellow when laid, turning green, then black. No significant difference in the size, shape, color or chorin character could be detected between the eggs of the three species.

Rhopalosiphum prunifoliae. The activities of this aphid, during the fall months are very similar to those of *A. roseus*. The winged females return to apples at about the same time and give birth to a generation of wingless oviparous females which are commonly deposited in colonies of from 2 to 8 or 10. They differ from *A. roseus* in that they do not exhibit a preference for the leaves on any particular area of the tree, but since most of the foliage is located on the outer part of the tree, it follows that a majority of the population will be found here.

The oviparous females are light green to greenish yellow in color with blackish legs and antennae. The antennae are short, reaching only to the first abdominal segment, the cornicles are very short, not larger than the next abdominal segment, the body is slender and pointed at the pos-

terior end. Oviposition may occur before that of the rosy aphid but mostly during the same period. Sometimes many of the females are immature and fall with the foliage following freezing weather. The winged males return late in October and in November and mate with the wingless oviparous females. Occasionally the fall forms of this aphid appear in enormous numbers and deposit a corresponding large number of eggs. Mostly these are found on the smaller outside branches on the smooth bark, in cracks, scars, at the base of buds and fruit spurs, etc. These are the aphid eggs that are usually observed when examining a dormant apple tree. An abundance of the eggs of this aphid does not indicate a corresponding relative abundance of *A. roseus* eggs.

Aphis pomi. The biology of this aphid differs from that of the two species just discussed in that it inhabits the apple during the entire year, and in that it produces a generation of wingless males and oviparous females with no intervening generation of winged migrants. The females are dark green in color; the antennae long, reaching about half way between the first abdominal segment and the base of the cornicles; cornicles long and flanged at the tip; body more or less pear shaped. The males resemble the females in appearance but are only about half as large and yellowish green in color. The sexual forms become mature the last of September or early in October. Oviposition continues through October and most of November whenever the temperature is about 40 degrees F. or above.

The eggs are laid either directly on the water sprouts, on which late colonies of the aphids had been feeding or in the immediate vicinity. Young trees are especially favored for the development of the sexual forms and deposition of eggs.

Control Experiments

The rosy aphid is the most destructive species of the three; consequently it has been given more consideration with respect to its susceptibility to control. Three different possibilities suggested themselves:

(1) control by preventing the return of the fall migrants,
(2) destroying the oviparous females before eggs were laid, and
(3) applying an ovicide to the trees after oviposition was completed.

1. During the fall of 1929 defoliation experiments were tried in which the foliage was killed in September just before the fall migrants began to return. Again in 1930 they were repeated later when the oviparous fe-

Table 1. Rosy Aphid Control, 1929–30

Treatment	Number trees	Rosy aphid clusters per tree	Per cent control	Remarks
Sodium arsenite 5 lbs. per 100 gals. September 13, 1929	6	2	93.6	Severe injury
Sodium nitrate 5 lbs. per 100 gals. September 13, 1929	5	5	81.49	Moderate injury
Tar oil 5 per cent Spring 1930	11	0.36	98.63	No injury
Paraffin oil 8 per cent Spring 1930	10	26	4.7	Retarded growth
Lime-sulfur Black Leaf 40 1–800 Delayed dormant 1930	11	8	70.37	No injury
Checks	10	27	——	

males were present but before oviposition began. Sodium arsenite and nitrate of soda were used as they proved the most effective materials of many tried for this purpose. The results are given in Tables 1 and 2. An interesting observation was that the winged migrants returned to these trees and would concentrate on any small green area and deposited their young there. These treatments, however, resulted in severe twig and limb injury—more severe with the sodium arsenite than with the nitrate of soda.

2. During the fall of 1930 an oil nicotine spray was applied to the foliage at intervals during the period of activity of the aphids. The aphids were easily killed when hit with this spray, but the foliage at this time is usually dense and many of the leaves may have become twisted and cupped so that it is very difficult to do a 100 per cent job of spraying. Also the spraying must be done from the ground and underneath the tree to cover the undersides of the leaves. Many varieties, such as Ben Davis and Baldwin, are not picked at this time; so even tho good control was obtained it does not appear to be a practical procedure. See Table 2 for control data.

TABLE 2. ROSY APHID CONTROL BY FALL TREATMENTS, 1930[1]
RHODE ISLAND GREENINGS, GENEVA, N. Y.

Treatment	Date applied	Number trees	Average number aphid clusters per tree	Per cent control
White mineral oil 2 per cent Black Leaf 40 1–800	Oct. 7	10	34.9	75.72
White mineral oil 2 per cent Black Leaf 40 1–800	Oct. 17	10	9.6	93.32
White mineral oil 2 per cent Black Leaf 40 1–800	Oct. 22	9	15.3	89.36
Linseed oil 2 qts. Tobacco dust 40 lbs. } 100 gals.	Oct. 17	10	34.9	75.72
Sodium nitrate 1 lb. per gal.	Oct. 17	12	17.5	87.83
Checks		10	143.7	

[1]Aphid clusters counted June 9, 1931.

3. Tar washes having proved effective as an ovicide when applied as a dormant spray in the spring were applied during the fall of 1931, 1932, and 1933. The applications were made late in November after the foliage had dropped from the trees, at which time oviposition by the aphids was complete. When the tar oil spray was applied to the aphids it appeared to be as effective in killing them as it did the eggs. No data relative to control was secured following the 1931 application but no injury to the trees resulted. The control data for 1932–33 are given in Tables 3 and 4. This was like 1931–1932, a mild winter and no injury other than a slight retardation of the buds could be seen.

TABLE 3. THE RELATIVE EFFICIENCY OF FALL AND SPRING APPLICATIONS OF TAR OIL AGAINST THE ROSY APPLE APHID, 1932–33. RHODE ISLAND GREENINGS, GENEVA, N. Y.

Treatment	Time of application	Number trees	Average number rosy aphid clusters per tree	Per cent control
Tar-lubricating oil emulsion[1] 5 per cent	Fall 1932	5	1	96.34
Tar-lubricating oil emulsion 5 per cent	Spring 1933	7	0	100.00
Tar-lubricating oil emulsion 3 per cent	Fall 1932	5	0.2	99.27
Tar-lubricating oil emulsion 3 per cent	Spring 1933	5	0.44	98.39
Lime-sulfur 1–40 Black Leaf 40 1–800	Delayed dormant 1933	5	0	100.00
Checks		7	27.3	

[1]Tar-lubricating oil emulsion = tar oil 65 per cent, lubricating oil 15 per cent.

TABLE 4. THE RELATIVE EFFICIENCY OF DORMANT OIL SPRAYS IN CONTROLLING THE ROSY APPLE APHID, 1932–33. RHODE ISLAND GREENINGS, HILTON, N. Y.

Treatment	Time of application	Number rosy aphid clusters per tree	Per cent control
Tar-lubricating oil emulsion[1] 5 per cent	Fall 1932	18	97.50
Tar-lubricating oil emulsion 5 per cent	Spring 1933	0	100.00
Tar-lubricating oil emulsion 7 per cent	Fall 1932	13	98.20
Tar-lubricating oil emulsion 7 per cent	Spring 1933	0	100.00
Paraffin oil 2½ per cent Cresylic acid ½ per cent	Green tip 1933	12	98.36
Lime-sulfur 1–40 Black Leaf 40 1–800	Delayed dormant 1933	72	90.00
Checks		718	——

[1]Tar-lubricating oil emulsion = tar oil 85 per cent, lubricating oil 15 per cent.

Since the tar oil had proved ineffective in controlling San Jose scale, and since the combination of oil and cresylic acid appeared promising in controlling the aphids, that combination was applied along with the tar oils the fall of 1933. The winter of 1933–34 was very severe in western New York, the temperature falling to —31 degrees F. at Geneva and being below 0 degrees for 12 days in February. This resulted in severe injury to many apple trees and furnished an excellent opportunity for studying the effect of fall and spring applications of dormant oil sprays. The effects of some tar and lubricating oils when applied in the fall as compared to the spring are given in Table 5.

TABLE 5. EFFECT OF DORMANT OILS ON THE DEVELOPMENT OF WINTER INJURED TREES, 1933–34. RHODE ISLAND GREENINGS, GENEVA, N. Y.

Treatment	Time of application	Per cent normal bloom	Per cent set of fruit
Tar-lubricating oil emulsion[1] 2 per cent	Fall 1933	96.41	57.06
Tar-lubricating oil emulsion 2 per cent	Spring 1934	95.94	41.72
Tar-lubricating oil emulsion 3 per cent	Fall 1933	94.49	58.62
Tar-lubricating oil emulsion 3 per cent	Spring 1934	95.26	47.18
Tar-lubricating oil emulsion 5 per cent	Fall 1933	79.73	23.60
Tar-lubricating oil emulsion 5 per cent	Spring 1934	87.39	22.30
Tar-lubricating oil emulsion 7½ per cent	Fall 1933	75.78	18.42
Paraffin oil 3 per cent Cresylic acid 1 per cent	Fall 1933	47.67	24.42
Paraffin oil 3 per cent Cresylic acid 1 per cent	Spring 1934	88.57	43.25
Paraffin oil 3 per cent	Spring 1934	85.48	57.64
Check	——	96.09	62.80

[1]Tar-lubricating oil emulsion = tar oil 85 per cent, lubricating oil 15 per cent.

SUMMARY

The fall activities of *A. pomi*, *A. roseus*, and *R. prunifoliae* are independent of each other and the relative abundance of each species varies considerably from year to year.

The eggs of *A. pomi* were found only on water sprouts and on young trees in the vicinity of late surviving colonies of the summer forms.

The eggs of *R. prunifoliae* are laid principally on the smaller branches in exposed situations and comprise the bulk of the eggs one sees on casual observation of dormant trees.

The eggs of *A. roseus* are laid mainly on the larger branches in the vicinity of the fruit spurs, in cracks and under rough bark where they are not readily observed.

These aphids withstood a temperature of 10 degrees F. but succumbed at a temperature of 7 degrees F. Egg laying and other activity ceases at or below a temperature of about 40 degrees F.

Control by defoliation was possible but injury to the trees followed. Fall control by nicotine sprays was obtained but such treatment is not practical.

Mineral oil and cresylic acid applied in the fall of 1933 was highly injurious to the trees. This combination was less injurious when applied the following spring. It produced no harmful effects when it followed a mild winter.

Tar lubricating oil sprays (65 per cent tar oil, 15 per cent lubricating oil) caused no injury when applied during the falls of 1931 and 1932. When applied preceding the severe winter of 1933–34 the weaker dilutions appeared to be a little less injurious than when applied the following spring, but at the higher concentrations no difference was apparent. Tar oils applied either in the fall or spring were effective in controlling the rosy aphid.

MR. W. S. HOUGH: What is the character of the injury following defoliation of the trees?

MR. T. WALTER REED: Just the killing of the terminal branches, the last two or three years' growth.

MR. C. R. CUTRIGHT: In the autumn, if the leaves are dropping with heavy frost or light freeze, will the aphids crawl back up the trees after the leaves have dropped?

MR. REED: Not a very large number of the rosy aphids ever fall with the leaves. They are generally mature at the time the leaves become frosted and before the leaves drop they crawl on the branches. A few mature aphids will crawl back if the leaves fall close to the trunk.

MR. J. M. GINSBERG: Was there any particular purpose in using 1 per cent cresylic acid when ½ of 1 per cent was sufficient?

MR. REED: We used the 1 per cent in this particular test with the idea of determining the safety limits of the cresylic acid.

IMMEDIATE AND RESIDUAL EFFECTS OF CERTAIN INSECTICIDES ON THE WHITE APPLE LEAFHOPPER[1]

By HAROLD M. STEINER[2]

The biology and control of the white apple leafhopper, *Typhlocyba pomaria* McAtee, has been the subject of investigation in the Hudson Valley fruit district since 1930. The data presented in this paper were obtained in 1934 and represent one phase of the control studies. Since the first year's tests, several spray combinations have shown sustained toxicity to the nymphs when treatments were applied after the peak and before the completion of hatching. The principal object in the past

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[2]The writer wishes to express his appreciation for the guiding suggestions of Dr. P. J. Chapman under whose supervision this work was completed. He is also indebted to Mr. G. W. Pearce, Chemist at the New York State Experiment Station, for all of the chemical analyses referred to in this paper.

season's tests was to determine more precisely the residual effects of some of the more promising combinations when used as single spray treatments against second brood nymphs.

Toxicity tests were conducted on heavily infested trees between 7 and 10 years of age. A power sprayer delivering a mist spray at 400 pounds pressure was used in making all treatments. The nymphal population on ten branches of each test tree was counted before sprays were applied and the efficiency of the several treatments was calculated on the basis of subsequent examinations.

The insecticidal combinations tested in 1934 were applied during a four day period from August 22 to August 25 at the peak of hatching. Approximately 40 per cent of the hatching had taken place by August 22 and this had progressed to 60 per cent on the latter date. It was possible to obtain the initial nymphal count in all instances immediately (10–15 minutes) prior to treatment. The efficiency of the treatments was determined from counts made at intervals of 24, 72 and 144 hours after spraying. The reduction, if any, evident in the 24 hour count has been termed the "immediate kill". The "residual kill" was determined from counts taken 144 hours after spraying by comparing the populations of nymphs developing on sprayed and unsprayed trees after the 24 hour count.

It has been assumed that the rate of hatching would have been proportional on sprayed as on unsprayed foliage. This assumption necessitated the examination of eggs in foliage to determine whether they were affected by spray combinations which killed the nymphs. It was found that the eggs were apparently not affected by nicotine sulfate in combination with soaps and oils at the amounts used in these experiments. In some instances, however, it was found that nymphs were sometimes killed in the process of hatching.

The results obtained with some of the materials tested in 1934 appear in Table 1. Attention is called to the fact that nicotine sulfate in most of its combinations has provided an effective residual action against the nymphs. Loro, Lethane Jr., and Pyagrol are types of preparations which may give a good immediate kill but apparently have little effect on nymphs which hatch some hours after treatment.

As will be seen in Table 1, the best immediate and residual kills were obtained with nicotine sulfate in combination with summer oil or soap. No practical difficulties were experienced in the use of soap with the water available for spraying in these experiments; the calcium and magnesium salt content in waters from three widely separated sources analyzed 75.5, 85.1 and 88.8 parts per million expressed as calcium carbonate. The oil emulsion or perhaps other supplements, not as yet tested, would probably be preferred to many soaps where hard waters are encountered. For reasons of compatability the soap or oil-emulsion nicotine sulfate combinations would probably not prove suitable for treatment of the first brood in this area, since the leafhopper insecticide would necessarily be included in one of the early season sprays where sulfur and lead arsenate would be present. Such difficulties are not encountered in the Hudson Valley in the control of the second brood

TABLE 1. CONTROL EFFICIENCY OF CERTAIN INSECTICIDES WHEN APPLIED TO THE WHITE APPLE LEAFHOPPER DURING THE PEAK OF HATCHING

Materials used[1]	Rate per 100 gals.	Date of spraying August	No. of nymphs on ten marked branches: Initial count	Estimated hatching within 144 hrs. after spraying	Percentage kill: Immediate (24 hour count)	Residual (144 hour count)
Ammonium sulpho soap Nicotine sulfate	1 pt. ⅔ pt.	22	783	589	78.6	16.3
Bentonite-sulfur (Kolofog)	6 lbs.	23	808	462	82.8	18.8
Bentonite-sulfur (Kolofog) Nicotine sulfate	6 lbs. ⅔ pt.	23	800	458	98.4	71.3
Bentonite-sulfur (Kolofog) Nicotine sulfate Ammonium sulpho soap	6 lbs. ⅔ pt. 1 pt.	23	838	479	99.0	60.3
Summer oil (Orthol K Med.) Nicotine sulfate	2 qts. ¼ pt.	23	1077	616	99.8	74.4
Summer oil (Orthol K Med.) Nicotine sulfate	2 qts. ⅔ pt.	23	859	491	100.0	90.2
Black Leaf 155	5 lbs.	23	936	535	96.8	45.2
Loro	¾ pt.	23	825	472	96.5	0.0
Lethane Jr.	2 qts.	23	703	402	98.1	0.0
Pyrethrum extract in Penetrol (Pyagrol)	1 pt.	24	704	305	85.5	0.0
Nicotine sulfate with soap No. 1 with soap No. 2 with soap No. 3 with soap No. 4 with soap No. 1 with soap No. 2 with soap No. 3 with soap No. 4	½ pt. 3 lbs. 3 lbs. 3 lbs. 6 qts. ½ lb. ½ lb. ½ lb. 1 qt.	25 25 23 23 25 25 25 25	1257 863 587 821 919 1058 815 993	500 343 336 470 366 421 320 395	99.7 99.8 100.0 99.2 99.6 99.7 99.6 99.7	68.0 83.3 44.4 11.6 84.6 90.6 89.3 90.3
Nicotine sulfate with soap No. 1 with soap No. 2 with soap No. 3 with soap No. 4 with soap No. 1 with soap No. 2 with soap No. 3 with soap No. 4	⅔ pt. 3 lbs. 3 lbs. 3 lbs. 6 qts. ½ lb. ½ lb. ½ lb. 1 qt.	25 25 23 23 25 25 25 25	860 584 610 745 891 839 788 842	346 232 349 426 354 334 313 335	99.8 100.0 100.0 99.5 100.0 100.0 100.0 100.0	83.7 91.7 56.5 27.1 95.9 96.0 95.4 92.8
Population of nymphs on 750 leaves of six unsprayed trees	3385	3902	4419	4725	5031	5482	5933	6136	6339	6607
Date—August	22	23	24	25	26	27	28	29	30	31

[1]The soaps to which reference is made by number are as follows:
Soap No. 1—Proctor and Gamble, Clean-Quick Soap Flakes.
Soap No. 2—Proctor and Gamble, Ivory Soap Flakes.
Soap No. 3—Beaver-Remmers-Graham, Pine Tar Soap Flakes.
Soap No. 4—Beaver-Remmers-Graham, Liquid Pine Tar Soap.
Nicotine sulfate (Black Leaf 40).
[2]These estimates were figured from the initial counts by assuming that the rate of hatching was proportional on sprayed as on unsprayed foliage.

as the use of fungicides and stomach insecticides is discontinued by mid-July or earlier. All soaps, with the exception of ammonium sulpho soap, have given a uniform *immediate* kill but considerable differences have occurred in *residual* kill, varying with the kind of soap and with the rate at which it was used. The residual kill obtained with the soaps and nicotine sulfate was consistently higher with all brands when the soap was used at a ½–100 rate than when used at a 3–100 rate.

The residual action of nicotine sulfate sprays is further demonstrated in a laboratory test set forth in Table 2. Foliage was treated with spray mixtures and permitted to dry for 24 hours. First and second instar nymphs were then placed on the foliage at intervals of 24, 48, 72 and 96 hours after spraying and the percentage kill was recorded in each test after 24 hours. In this experiment it may be seen that nicotine sulfate alone was not as effective as when it was used with ½ or 1 pound of soap and that when used alone or with ½ or 1 pound of soap it was more effective than in combination with 3 pounds of soap in 100 gallons of water. An analysis of water used in this experiment showed a magnesium and calcium salt content of 75.5 parts per million.

TABLE 2. THE TOXICITY OF NICOTINE SULFATE AND SOAP RESIDUES TO NYMPHS OF *Typhlocyba pomaria*. A LABORATORY EXPERIMENT

Materials used[1]	Rate per 100 gals.	Percentage kill, with nymphs placed on sprayed foliage at various intervals after treatment: 24 hours	48 hours	72 hours	96 hours
Nicotine sulfate	⅔ pt.	95	69	70	42
Soap flakes	3 lbs.	0	0	—	—
Nicotine sulfate Soap flakes	⅔ pt. 3 lbs.	83	68	39	5
Nicotine sulfate Soap flakes	⅔ pt. 1 lb.	94	98	95	68
Nicotine sulfate Soap flakes	⅔ pt. ½ lb.	98	97	93	77
Check—no treatment		0	0	0	0

[1]The soap flakes used were Clean-Quick, a Proctor and Gamble soap product. Nicotine sulfate—(Black Leaf 40).

Nicotine analyses were made to determine the persistence of nicotine on foliage sprayed in the orchard with nicotine sulphate and soap. In general the results indicate that a correlation existed between high *residual* kill and the amount of nicotine recovered.

STRAWBERRY LEAF ROLLER CONTROL BY NON-POISONOUS INSECTICIDES[1]

By RAY HUTSON, *Michigan State College, East Lansing, Michigan*

The strawberry leaf roller, *Anyclus comptana*, is a serious pest of strawberries in all the important strawberry-growing districts in Michigan. The common method of control consists in sprays of lead arsenate just before and just after the time the plants are in bloom for standard varieties. The widely used supplemental practice of burning over the strawberry field is not practiced generally in Michigan for the reason that conditions of moisture, windage, and soil are not conducive to a quick, rapid fire, but rather to a tendency to smolder in spots. However, in the case of ever-bearing strawberries the danger of residue is greater than with standard varieties because ripe berries are

[1]Journal Article No. 203 (n.s.) from the Michigan Agricultural Experiment Station.

present all the time. Consequently, the marketing of ever-bearing strawberries would be jeopardized to such an extent that the growers engaged in this particularly specialized branch of agriculture have been loath to use arsenical sprays. It may be well to point out that, though the growing of ever-bearing strawberries in most sections of the United States is more or less of a novelty, this out-of-season delicacy affords a considerable revenue to growers living in Minnesota, Wisconsin, and Michigan, since the berries are not ordinarily marketed until after all other strawberries are gone.

Strawberry leaf roller infestation is particularly destructive on ever-bearing strawberries, since the growth habit of the plant and the cultural practices followed are expecially favorable to the growth and multiplication of this insect. It is a common practice to pinch off all the blossoms and cultivate the plants intensively during the months of May, June, and July. As a result of this treatment, the plants grow luxuriously and furnish a maximum of new foliage on which the strawberry leaf roller population is built up to a high point by about the first of August, when the harvesting of berries is in full swing. As a result of the conditions outlined, it is not an uncommon thing to see practically an entire crop of ever-bearing strawberries destroyed by strawberry leaf rolloer.

In the summer of 1933, test plots of several materials were planned in a field of ever-bearing strawberries, heavily infested by this pest. Each plot consisted of a ten-rod row adjacent to an unsprayed check row of the same length. Every test was triplicated and the results represent an arithmetical average of the counts upon the plots receiving each treatment. In these tests all insecticides were applied with hand dusters or sprayers. The results were taken by counting the number of live leaf rollers on each plot by a careful examination of each plant seven days after spraying. Table 1 is a compilation of the results of these counts.

TABLE 1. RESULTS OF NON-ARSENICAL INSECTICIDE TESTS AGAINST STRAWBERRY LEAF ROLLER, JUNE 1933

Treatment	Dilution	Rate per acre	Live Leaf Rollers on 10 rod row at end 10 days
Pyrethrum Dust	50 per cent John Powell Activated "A" Dust plus 50 per cent talc	30 lbs. dust	51
Pyrethrum plus Verdol	1 qt. Evergreen plus 1 gal. Verdol in 100 gals. spray	125 gals. spray	260
Pyrethrum	1 qt. Pyagrol in 100 gals. spray	125 gals. spray	202
Derris	25 lbs. ground derris (2 per cent rotenone) plus 75 lbs. talc	30 lbs. dust	74
Derris	5 lbs. ground derris (2 per cent rotenone) plus 2 lbs. soap chips in 100 gals. spray	125 gals.	68
Calcium Arsenate	10 per cent calcium arsenate plus 90 per cent talc	30 lbs. dust	107
Black Leaf 40 plus Verdol	½ pt. B. L. 40 plus 1 gal. Verdol in 100 gals. spray	125 gals.	204
Black Leaf 50 plus Verdol	½ pt. B. L. 50 plus 1 gal. Verdol	125 gals.	232
Untreated Check			267

Subsequent to the experiments described some of the more promising formulas were brought to the attention of growers having infestations

of strawberry leaf roller. The pyrethrum and derris dusts seemed to give the best controls when used by growers during 1933. During 1934, derris dusts and sprays were used by many growers of ever-bearing strawberries. While most users of non-arsenical insecticides for control of strawberry leaf roller inclined to the use of dusts, because they were more readily applied, those who used a proprietary mixture of soap and ground derris reported good control.

The reductions in population of strawberry leaf roller on the plots receiving pyrethrum and derris dusts were of the magnitude of seventy-five per cent. In comparison with percentages of kill required against insects having a higher reproducive potential, e.g. aphis, this would be insufficient for control.

The applications, however, came at the time when second brood larvae were most active and was sufficient to eliminate strawberry leaf roller as a factor in crop production for the rest of the season.

Pyrethrum and derris dusts gave a significantly better control than did pyrethrum sprays with and without spreading agents, while the result of spraying with ground derris plus a spreader gave control practically as good as dusts.

Calcium arsenate was included in these tests in order to furnish a comparison of controls by arsenical, and non-arsenical insecticides.

The controls secured by the use of derris and pyrethrum insecticides exceed those secured through the use of other materials and inasmuch as they also eliminate the danger of residue constitute a ready means of stopping attacks by these insects while fruit is ripening.

MR. W. P. FLINT: I would like to ask Mr. Hutson what dates he is going to recommend for the application of those sprays in relation to the growing of the plant.

MR. RAY HUTSON: The application of any material on ever-bearing strawberries will have to be a sort of emergency proposition. That is, I will simply circularize the growers of whom we have a list and tell them that when these insects become troublesome they can control them with one or the other of the sprays that I mention or the dusts.

I do not believe that the ever-bearing strawberry as cultivated with us lends itself to any sort of scheme whereby you can say that on the 15th of June they will be in a certain stage, because this fellow has a market that takes berries at a certain time, and the other fellow is getting ready for Labor Day. So there is no uniformity about the fruiting.

THE IMPORTANT SHADE TREE INSECTS IN 1934

By E. P. FELT, *Bartlett Tree Research Laboratories, Stamford, Conn.*

The abundant and unsightly webs of the apple tent caterpillar and the extensive stripping by canker worms, mostly by the fall canker worm were both marked features of the past season.

The apple tent caterpillar, *Malacosoma americana*, although extremely prevalent should be considered more as a nuisance than an insect plague, since it confines itself largely to the relatively worthless wild cherry and ordinarily is readily controlled on fruit trees by spraying, though the almost unprecedented abundance of egg masses laid the past season suggests there may be great difficulty next spring in preventing serious injury to some of the more badly infested fruit trees. Some of these have five to ten times the number necessary to produce complete defoliation. The coming season presumably will mark the peak of the outbreak and there will be relatively few of the pests in 1936.

It is interesting to note that the related forest tent caterpillar, *Malacosoma disstria*, was abundant the past season in restricted areas in southern New Hampshire, somewhat numerous at Lenox, Mass., and was found in small numbers at Stamford, Conn. It is possible that these occurrences are forerunners of greater abundance in 1935.

The outbreak of the fall canker worm, *Alsophila pometaria*, followed a great abundance of the insect and extensive though somewhat localized injury the preceding season. The pests were most numerous last spring in areas adjacent to or outside the sections badly affected in 1933, this being eastern and southern New England, southern New York and northern New Jersey. The extreme abundance of the fall canker worm is indicated by the finding within five feet of the ground on the six-inch trunk of a small birch tree 200 egg masses, the eggs ranging in number from 20 or 25 to 200 and with a probable average of about 100. That is, there were some 20,000 eggs on possibly one fourth of the bark surface of a relatively small tree. An ash branch with a length of a little less than four feet and with a few short limbs, bore 14 good sized egg masses. This extremely heavy infestation resulted in very general defoliation, and in the case of late developing trees, such as ash and black walnut, the branches were practically bare of foliage until the last of May, due to the canker worms devouring the young leaves as rapidly as they appeared. Hickories were also badly injured by the canker worm. Many red and black oaks, especially on the higher dry ridges, were defoliated.

There was no evidence to indicate that the eggs of this insect were affected by the extreme cold of last winter. It was noted that the hatching period extended over some weeks, and here and there one could see unquestioned evidence of the drifting in the wind of recently hatched canker worms. This latter is probably of some importance and most likely explains the inability in some cases to protect the tops of trees near badly infested woodlands. That is, canker worms drifted in such numbers and over a sufficient period so that one spraying could not be depended upon to protect the young foliage. This was also evident in the case of banded trees, some being defoliated and others escaping with practically no injury, the difference probably being due to drifting canker worms. This was true even of trees standing in the open and some distance from sources of infestation. It is evident that sticky bands cannot be depended upon in areas where there is a generally severe infestation. There is some danger of injury to the tree unless the adhesive is applied to a heavy non-permeable paper tacked or fastened

to the bark. It is believed that as a rule spraying is preferable to banding as a means of control.

The spring canker worm, *Paleacrita vernata*, was present in some numbers and in a few localities may have been the dominant species, though in most sections the fall canker worm was by far the more abundant.

The two-lined chestnut borer, *Agrilus bilineatus*, favored presumably by the weakening of the oaks in the dry seasons of 1930 to 1932 inclusive, the defoliation in earlier years by leaf rollers and the past two seasons by canker worms, multiplied tremendously, and as a consequence numerous oaks on the higher ridges, especially in southern Westchester County and along the North Shore of Long Island, have been generally attacked by these borers and a considerable proportion of the trees killed. In some instances, this may run to some 25 per cent of the stand. The woodland infestations may be somewhat general in nature and numerous trees here and there succumb, or they may be spotted, and most of the oaks in a roughly oval area, comprising half an acre to an acre, may be killed. The former obtains in areas where there is a somewhat scattering, mostly old growth, and the latter in the younger stands which are usually in somewhat better condition. This two-lined chestnut borer is apt to concentrate on an individual tree or group of trees, and in not a few instances, oaks on the margins of lawns and adjacent to a badly infested woodland have been killed with practically no warning, so far as weakness due to drought or other effects are concerned. This borer is considered a dangerous enemy of trees in sections where oaks are grown under lawn or park-like conditions. The most effective control is spraying with poison the last of May or in early June to kill the beetles and feeding to stimulate vigor, since this insect is rarely troublesome on healthy trees.

The sugar maple borer, *Glycobius speciosus*, is a well known enemy of the sugar maple, which ordinarily receives little attention due to the fact that the effects of its work do not become apparent until several years after the damage has been caused and the apparently somewhat general assumption that dying or dead branches and scarred trunks are unavoidable in sugar maples. General injury to sugar maples exists in both the states of Vermont and New Hampshire, and apparently there is little attempt to remedy the trouble, although it is feasible to check the borer in the more highly prized sugar maples growing on lawns or under similar conditions. This type of injury is too commonly overlooked.

The locust borer, *Cyllene robiniae*, has become extremely abundant locally in southeastern New York, many young trees being so badly affected that they were in a wilting, almost dying condition the past season.

The elm leaf beetle, *Galerucella xanthomelaena*, continues to be abundant and injurious in southern New England, southern New York and New Jersey. The pest is an important one because of the great value of the elm as a shade tree and the further fact that if the foliage of elms is not sprayed and the trees are not kept reasonably vigorous, they are likely to become infested by the bark beetle, *Scolytus multistriatus*.

Since this insect is the principal vector of the Dutch elm disease, it greatly accelerates the distribution of the deadly infection in areas where it is allowed to become abundant. It is considered advisable to call attention to the fact that these various agencies have a causal relation one to the other and to add that a program of tree sanitation which does not take into account this relationship is very likely to fail in providing adequate protection for the elms under the really serious conditions now prevailing.

The beech scale, *Cryptococcus fagi*, known at Hartford, Conn., and Scarsdale, N. Y., is becoming established more widely and on account of its relation to the deadly *Nectria coccinea*, there is a probability of serious consequences following in areas where the insect becomes abundant.

The imported willow leaf beetle, *Plagiodera versicolora*, continues to be a serious pest in New England and New York State where it produces on favored species of willows an unsightly grayish foliage condition throughout much of the summer. The unchecked work of this insect, frequently supplemented by the recently introduced willow scab fungus, has resulted in the death of thousands of these desirable and picturesque trees.

A white pine weevil, *Pissodes approximatus*, a species very similar in appearance to the white pine weevil, *Pissodes strobi*, but differing in minor characteristics and in particular by its habit of working in the bark of the trunk, especially below the surface of the ground, was found to be the cause of the death of several transplanted pines at Stamford, Conn. These trees had a trunk diameter of less than two inches. They were standing in grass and the first visible evidence of infestation was the somewhat general browning of foliage on several branches. An investigation at this stage showed considerable boring, the stems being nearly girdled just below the surface of the ground. The trees died shortly after. It is possible that this insect is of more importance in pine plantings than has heretofore been suspected.

The Japanese scale, *Leucaspis japonica*, an introduced species somewhat well established locally in southern Connecticut and on Long Island, became extremely abundant at Freeport, L. I. last year. An examination this spring showed a high mortality rate, probably over 99 per cent, as a result of the unusually low temperatures of the preceding winter. The San Jose scale, *Aspidiotus perniciosus*, suffered to a nearly equal extent in the same locality.

THE PECAN TREE BORER IN DOGWOOD

By G. W. UNDERHILL

In the spring of 1931 a severe infestation of the pecan tree borer (*Synanthedon scitula* Harris)[1] was discovered in dogwood in one nursery in Virginia. A large block containing about 3,000 one-year old and 15,000 two-year old pink dogwood trees was involved.

[1]Determined by Dr. A. Busck.

This insect was noted as a pest of the pecan as early as 1904.[2] It is known by several common names, as pecan tree borer, pecan sesia, ninebark borer, and woody gall borer. Probably some other species have been confused with it, since the records refer to a great variety of hosts including oak, chestnut, dogwood, ninebark, hazel, cherry, apple, willow, beech, myrtle, loquat, pine, and pecan. The list would indicate a confusion with at least two species; viz., *Aegeria pyri* Harris in apple and pear, and *Synanthedon corrusca* Hy Edwards a probable geographic race[3] found in pecan in the South. The early records indicated that it developed chiefly in galls and other malformations, and in wounds. Engelhardt[3] seems to think that it has changed its habits and has become a bark and cambium pest. It is decidedly a cambium pest in dogwood in Virginia, but the trees with rough bark are most susceptible to injury.

Reports indicate a distribution of the insect from Florida to Canada and from Illinois to Mississippi. This borer probably occurs generally over the entire area east of the Mississippi River. In Virginia it is pretty generally distributed in dogwood but is not very common or abundant in native trees in the woods.

When the infestation was first noted in early June, 1931, about 15 to 19 per cent of the older nursery trees were infested. In October the percentage had jumped to approximately 39 per cent of the old trees, and the adjoining young stock showed an infestation of 20 per cent. In a separate large block of two-year stock, however, the infestation was only about 8 per cent. In October, 1932, about 36 per cent of the old stock and 8.5 per cent of the isolated young stock were infested; and in 1933, the infestation in the old stock was 40 per cent. These data indicate only a slight increase in the infestation, but the frass was somewhat more abundant and there were more borers per tree. In early October, 1931, the average number recovered in 35 trees was 1.6 borers; in October, 1932, the average for 77 trees was 2.8 per tree. As many as 14 borers have been removed in the fall from a single nursery tree about 3 inches in diameter. The probable reason why the number of infested trees remained about the same was that nearly all the trees with rough bark had already been infested.

A good many nursery trees in the above-mentioned block of older stock have died from borer attacks. Some have died each season, but more died in 1933 than in any other year. It is estimated that about 25 per cent of the trees were so seriously injured as to be unsalable. Severely damaged trees are easily broken off and many have been lost in this way. Many ornamental dogwoods in landscape plantings also have been severely damaged or killed in Virginia.

Young dogwood trees are attacked chiefly at the crown, but older trees may be infested in scars or in rough bark anywhere on the trunk or limbs.

The moths are Aegerids and have a wing expanse of about 18 mm. Their color is bluish-black and sulphur-yellow with some white on the head. The palpi are yellow and all the joints of the antennae are black.

[2]Herrick, G. W., Miss. Agr. Exp. Sta. Bul. 86:11–15, 1904.
[3]Engelhardt, G. P., Jour. Econ. Ent. 25:293, 1932.

The larvae are creamy white and have reddish-brown heads. Mature borers are about 12 to 13 mm. long. The procephalic shield has two oblique yellowish areas shaped somewhat like golf clubs on the posterior half.

The insect passes the winter in burrows as larvae from 3 to 12 mm. in length. Pupation begins in early spring. Cocooning may occur in April, at Richmond. By the middle or the last of May, 20 to 30 per cent have usually cocooned, and 15 to 20 per cent have changed to pupae. Pupae have not been collected after the first of October. The prepupal and pupal stages ranged from 2 to 4 weeks in length with an average of 18.4 days for 7 records in 1933, and 18.9 for 33 records in 1934. The prepupal period ranged from 4 to 12 days with an average of 6.6, and the pupal from 9 to 17 days with an average of 12.4 for 32 insectary records in 1934. The cocoons, which are made of excrement and bits of bark bound together by silk webbing, are usually located inside the burrow, under loose bark, or in cavities. They are located sometimes in trash and leaves and very rarely in the soil about the base of nursery stock.

Moths emerge over a period of approximately four months—from the middle of May to the last of September. The earliest record in the insectary was May 10 in 1932, and in the field May 11 in 1933. Emergence at Richmond begins around the middle of May or about the time pink dogwood flowers begin to fade and shed their petals, and when Eva Rathke weigelia just begins to come into bloom. The peak in emergence occurs in June and July. The life period of moths in cages ranged in 1932 from 2 to 12 days. While in 1934, the life period ranged from 3 to 18 days, with an average of 9 days for females and 7 for males.

In cages only small numbers of eggs were laid and practically all were infertile. In a series of 10 caged lots containing from 1 female and 1 male to 4 females and 3 males per cage, the average number laid per female was only 38 eggs for 21 individuals. The maximum number of eggs deposited by a single female was 116. Previous to 1934, none of the eggs laid in cages hatched, and in 1934 only two lots from a cage containing 4 females and 3 males proved fertile. The incubation period for these eggs, about the middle of July, was 8 to 9 days. Eggs are believed to be laid singly as a rule. In cages where small blocks of dogwood were used eggs were generally scattered on the rough bark, but were often placed side by side or close together in freshly cut grooves whether in the bark, cambium, or sapwood. More eggs were laid on cut surfaces than on the bark.

Larvae are present all through the year. During April and May the borers generally range from 4 to 13 mm. in length. After the middle of July, all sizes from 1 to 13 mm. occur. The borers feed in the bark and cambium and not in the sapwood. The small larvae may feed for several weeks in the bark before reaching the cambium. The tunnels run in an irregular course generally more or less spirally upward. The presence of a borer is indicated by pellets of excrement which are pushed out of the burrows. The pellets do not show much tendency to hang together except when held by webbing spun by the borer. The fine frass made by young borers is not easily detected in the field. Usually the larva is about

3 to 4 mm. long before signs of feeding become evident. The dogwood borer larvae are cannibalistic. On several occasions one borer has been observed in a tunnel, feeding on another.

Complete data on the number of broods and the developmental period have not been obtained. The life cycle, at least of most borers, is one year. Thirty-five borers from 2 to 9 mm. in length were collected in September, 1932, and introduced into uninfested caged trees. Of these, 27 established themselves and went through the winter. When examined July 29, 1933, 89 per cent of the 27 had pupated and 71 per cent had emerged, which indicates a one-year cycle. Measurements of head capsules indicate 6 instars. Some larvae kept in salve boxes and provided with dogwood blocks for food showed instars ranging in length from 8 to 50 days during the period from August 22 through October, 1934. The average for 22 records was 17.5 days.

Among natural enemies, internal parasites are most important. Predators and entomogenous diseases apparently are of little value. Ants and predacious beetle larvae have been taken in burrows and probably kill some borers, but no positive case was observed. A few trees have been noted where some bird, presumably the downy woodpecker, had dug in for borers. At times several dead larvae have been taken in burrows which were usually very moist or full of water or sap. From 10 to 16 per cent of the larvae were dead in some May and June collections. In the spring the sap flows very copiously from wounds and it is believed that the borers had drowned.

At least six species of parasites have been reared from larvae and pupae. Three species of Braconids parasitize the larvae and apparently prefer small to medium sized individuals. *Apanteles sesiae* Vier.[4] is by far the most important of the parasites. As high as 50 per cent of the larvae have been observed to be parasitized. In field collections only one parasite cocoon was noted in a burrow, and in all cage rearings only one developed from a borer larva. The parasite grub emerges at maturity and spins a white cocoon in a cell previously prepared by the enfeebled borer. *Microbracon sanninoideae* Gahan[4] and *Microbracon mellitor* Say[4] are much less common. Usually 4 to 6 dirty white cocoons occur in one borer cell, which indicates that more than one of either of these parasites develop in one larva. Two species of Ichneumon parasites have been reared from pupae collected in May and June. There were several *Phaeogenes ater* Cress.[5] and only one *Scambus* (*Itoplectis*) *conquisitor* Say[6] recorded. The small number reared indicates that these are not important parasites. About half a dozen borer cocoons were collected from which many small Chalcid parasites, *Hyssopus sanninoideae* Gir., emerged.

This borer has been a major nursery pest in one large block of dogwood trees during the past four seasons in Virginia. It is estimated that some 4,000 trees have been ruined or so seriously damaged that they will not recover. Scouting in the woods has indicated that this insect is pretty generally distributed in native dogwood, but the infestation was light.

[4]Determined by C. F. W. Muesebeck.
[5]Determined by Dr. R. A. Cushman.
[6]Determined by author.

CONTROL MEASURES FOR THE ARBOR VITAE LEAF MINERS, ESPECIALLY *RECURVARIA THUJAËLLA* (LEPIDOPTERA)

By A. E. Brower, *Field Entomologist, Maine Forest Service*

A leaf miner was reared from arbor vitae in Massachusetts by Packard and described as *Argyresthia thuiella* in 1871. Since that date this species has been mentioned many times as mining arbor vitae in Northeastern United States and Canada. In 1891 Walshingham described *Argyresthia freyella* from Texas. This has been recorded northward to Quebec mining in the leaves of red cedar and arbor vitae, and it was the subject of a short paper by W. E. Britton in 1933. In 1903 Kearfott described *Recurvaria thujaëlla* from specimens reared from arbor vitae in New Jersey. When an author speaks of a leaf miner in arbor vitae he is referring to one or more of these species, usually *Argyresthia thuiella* Pack. This has been recorded as the species present in injurious numbers in practically all cases; however, collections made on Mt. Desert Island and in central Maine have yielded largely *Recurvaria thujaëlla*, with fewer numbers of *Argyresthia thuiella* and occasionally a specimen of *A. freyella*. The following work was largely upon *Recurvaria thujaëlla*. Many other species of Argyresthia and Recurvaria are miners in leaves and fruiting parts of trees and herbacious plants, some being important economic species.

The insects are found on arbor vitae throughout the year. The moths emerge in June and July, and hide about their food plant. The eggs are laid on growing tips, the larvae mine until cold weather and again in the spring and pupate within or near the mines. Growing tips are entered usually one-fourth to one-half inch from the end, the larvae work downward, and the terminal and mined portions die and turn brown. Trees grown for ornamental purposes are especially subject to attack, since the insects seem to prefer thrifty trees in exposed or partly exposed situations. The great number of dead and brown tips on ornamental arbor vitae in Bar Harbor and elsewhere on Mt. Desert Island has led to many requests for control measures. The damage is even greater about Hartland, Lincoln, and other places in central Maine.

Dr. Felt suggested control methods in 1915. Clipping off the infested leaves during fall or spring and destroying them, and spraying with nicotine sulphate 1–800 plus soap early in July were suggested. This spray was aimed at the young larvae of *A. thuiella*. In 1922 Britton and Zappe applied a series of spring sprays against *A. thuiella*, but their results were inconclusive. A. M. Gillespie, Maine Forest Service, sprayed nine small trees on August 10, 1932 with nicotine sulphate, 1–1000 plus Penetrol 1–200. Counts made sixteen days later gave a kill of 27.5% with 3.43% dead in the checks. He sprayed four trees with each of the following on September 9, 1932 making counts three weeks later:

	No. larvae	No. dead	% dead
Nic. sul. 1–200 plus Penetrol 1–200	500	225	45.0
Nic. sul. 1–400 plus Penetrol 1–200	500	162	32.4
Check	500	63	12.6

In 1933 the author reared small lots of the leaf miners and made field collections in order to determine the periods of flight. A series of sprays was applied immediately after the flight periods were over in order to hit as many eggs as possible and to destroy the young larvae. In 1934 laboratory emergence and field collections showed that the main emergence period at Bar Harbor and in central Maine of *Argyresthia thuiella* is from June 21 to July 6, of *Recurvaria thujaëlla* from July 9 to 25, and that the few *Argyresthia freyella* secured were distributed over this whole period. The average incubation period of both *A. thuiella* and *R. thujaëlla* is probably somewhere near twenty days. Sprays were applied on August 10, with the results given in the table:

Sprays Applied August 8, 1933; Counts made April 25 to May 21, 1934.

	Larvae Dead	Alive	Total	% Dead
Nicotine Sul 1–400 plus a little soap...	133	17	150	88.66
Nicotine Sul. 1–600 plus a little soap	121	5	126	96.03
Lemon Oil 1–200	216	87	303	71.28
Check	31	23	54	57.40
Sprayed August 10, 1934; Counts Sept. 15 to Oct. 15, 1934.				
Nicotine Sul. 1–400 plus Penetrol 1–200	274	2	276	99.27
Nicotine Sul. 1–600 plus Penetrol 1–200	371	29	400	92.75
Nicotine Sul. 1–800 plus Penetrol 1–200	348	21	369	94.30
Nicotine Sul. 1–1000 plus Penetrol 1–200	307	30	337	91.09
Lethane 1–400 plus Lethane spreader	93	340	433	21.47
Red Arrow 1–400	62	375	437	14.18
Red Arrow 1–600	50	406	456	10.96
Check	54	373	427	12.64

The results given in this table must be evaluated with the fact in mind that the counts do not show the number of eggs killed by the sprays which were purposely applied near the end of the oviposition period of *Recurvaria thujaëlla*. Apparently all eggs are killed by strong nicotine sprays. Clipping hedges, especially if the clippings are destroyed, is doubtless of considerable value in controlling the the pest. On heavily infested ornamental trees spraying seems to be the only satisfactory control. These experiments show that nicotine sulphate, one part to 400 parts of water, with soap or Penetrol may be expected to give a high percentage of control of the arbor vitae leaf miners if applied near the end of the oviposition period. This time is during the first part of August at Bar Harbor and Lincoln, Maine. A preponderance of *Argyresthia thuiella* might make an earlier spray necessary.

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A PROGRESS REPORT ON THE INSECTICIDAL CONTROL OF THE MEXICAN MEALYBUG (*PHENACOCCUS GOSSYPII* T. AND CKLL.) ON GREENHOUSE CHRYSANTHEMUMS

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Since its first recorded presence in California in 1917 (*4*, *11*)[2] the Mexican mealybug (*Phenacoccus gossypii* T. and Ckll.) has spread widely over most of the Southern and Central States and as far north as Michigan and New York (*7*, *9*). In addition to attacking a wide range of plants (such as citrus, eggplant, tomato, okra, hollyhock, and geranium) it has become an outstanding pest of greenhouse chrysanthemums (*11*, *2*). Losses of from 40 to 50 per cent of this crop are not uncommon. It stunts the plants, distorts and mars the appearance of the foliage, attacks the flowers, and if not controlled will kill the plant outright. The severity of its attack is no doubt due in part to the large number of eggs laid. *P. gossypii* lays on an average 402 eggs, whereas *P. citri* has a reported average of 307 (*8*).

For controlling this pest, Wallace (Lieber, *5*) recommended nicotine oleate or oil emulsion, E. I. McDaniel (*6*, *9*) used nicotine sulfate 1–800[3] and sulfonated petroleum oil spreader, and Compton (*1*, *2*) advocated free nicotine 1–384, with the same spreader. The promising results obtained by the writer with calcium cyanide and kerosene emulsion were first reported in 1933 (Weigel, *12*) and 1934 (*10*). More recently Compton (*3*) has recommended hydrocyanic-acid (HCN) gas generated from sodium cyanide and dilute sulphuric acid.

SPRAYS AND DUSTS.—A number of dusts and sprays have been tested on infested chrysanthemums under greenhouse conditions, and the results are shown in Table 1. The applications were made as thoroughly as possible, the dusts being applied with a small hand duster and the sprays with a paint sprayer at 15 pounds' constant pressure. The mortality counts were made 4 or 5 days after the application, all eggs being removed shortly after spraying and in some cases being set aside for a record of hatching.

The dusts had little effect. Just recently sulphur dust (300 mesh) was tried. It had little effect on the active stages but killed considerable numbers of eggs (82.2 per cent of 621 eggs). Further tests corroborated these results, indicating that sulphur dust has some promise, but larger-scale tests have not yet been made. Of the sprays, those of nicotine were evidently the least effective even where the other extractives of tobacco were present. Both the derris and pyrethrum sprays when used with the same wetting agent were more effective than nicotine. The organic thiocyanates, especially the mixture of lauryl and other similar aliphatic thiocyanates, killed slightly more of the active stages than any of the above, were tolerated by the plant, and in addition had an exceptional

[1]The writer is indebted to Dr. C. A. Weigel for general direction of this work.
[2]Italic numbers refer to Literature Cited.
[3]Unless otherwise stated all concentrations given in text or tables are by volume.

toxic effect on the eggs. In addition to its high contact action at the time of spraying, recent tests have shown definitely that this spray exerts a residual toxic action over a period of several days after spraying. Young first-stage nymphs and nymphs in the process of hatching are especially affected. Apparently there is a fumigating effect on some of the eggs. The present cost of some of the thiocyanates compares very favorably with that of kerosene emulsion and they appear promising for use where a spray is needed. The 10-per cent kerosene emulsion was the highest in effectiveness against the active stages, and it killed a considerable number of the eggs. The highly refined, lighter-gravity kerosene (98 per cent unsaturated, 48.6° Bé.) in either the pure form or the emulsion form was definitely less effective than the ordinary kerosene (43.4° Bé.) emulsion.

TABLE 1. EFFECTIVENESS OF VARIOUS SPRAYS AND DUSTS AGAINST THE MEXICAN MEALYBUG

Insecticide	Nymphs, pupae, and adults		Eggs	
	Total number	Per cent killed	Total number	Per cent killed
Dusts				
Derris (4 per cent rotenone)	2,094	10.5	199	7.0
Pyrethrum (per cent pyrethrins, 0.54 pyr. I, 0.70 pyr. II)	810	6.9	148	10.0
Tobacco powder	1,436	3.1	277	4.3
Sprays				
Kerosene emulsion[1] 10 per cent	1,129	97.3	143	44.7
Refined kerosene (undiluted)	1,031	72.3	136	22.8
Refined kerosene emulsion 10 per cent	1,045	81.0	312	29.5
Thiocyanates No. 1[2] +soap[3]	1,169	88.1	206	82.0
Thiocyanates No. 2[4] +soap[3]	956	76.1	231	64.5
Nicotine sulfate 1–800 +soap[3]	665	27.1	—	—
Nicotine sulfate 1–800 +S. P. O.[5]	381	0.8	—	—
Nicotine +other tobacco[6] extr.	356	15.7	—	—
Pyrethrum extr.[7] +soap[3]	535	57.4	—	—
Pyrethrum extr.[7] +S. P. O.[5]	319	9.1	—	—
Derris extr.[8] +soap[3]	415	58.5	—	—
Derris extr.[8] +S. P. O.[5]	380	15.5	—	—
Soap alone[3]	1,104	0.8	244	5.3
Petroleum white oil emulsion (1 per cent oil)	461	24.1	—	—
Untreated check	758	1.2	236	3.8

[1]Water, 1 gallon; potash fish oil soap, ½ lb.; ordinary kerosene, 2 gallons. Stock emulsion diluted 1–6 by volume. Emulsions of 2½, 5, and 7½ per cent were also tried, giving 45, 69, and 81 per cent kill, respectively.

[2]A 1–600 dilution of a proprietary product containing lauryl and other similar aliphatic thiocyanates in mixture with the ammonium salt of a sulphonated fish oil. At the dilution used the spray is believed to have contained 83 mg. of mixed thiocyanates per 100 cc.

[3]Potassium coconut oil soap (0.25 and 0.33 per cent dry soap by weight). The latter strength was used only with nicotine, pyrethrum, and derris sprays.

[4]A 1–400 dilution of a proprietary organic thiocyanate spray of unknown concentration.

[5]S.P.O. =sulfonated petroleum oil used at a concentration of 0.5 per cent by volume.

[6]Contained 9 per cent nicotine as well as other tobacco extractives, and spray was diluted to contain near 0.14 grams of nicotine per 100 cc.

[7]Diluted to contain pyrethrins 1–5,000 by weight.

[8]Diluted to contain rotenone 1–10,000 by weight plus other derris extractives.

Some greenhouse tests were made of the efficiency of the 5 and 10 per cent kerosene emulsion sprays at 25, 100, 200, and 300 pounds' pressure applied very thoroughly with a gas engine greenhouse sprayer, the aim being to ascertain whether an increase in pressure would give a difference in penetration and result in an increased mortality. Of the active stages the 5 per cent emulsion killed 88, 84, 81, and 95 per cent in the order of increasing pressure and from 3 to 9 per cent of the eggs. The 10 per cent emulsion killed 98, 97, 98, and 98 per cent of the active stages (in the same order) and from 23 to 56 per cent of the eggs. Approximately 1,000 mealybugs and from 167 to 594 eggs were used in each test. The variation in pressure seemed to make little significant difference in

effectiveness of either the 5- or 10-per cent kerosene emulsion. Another later series corroborated this result. Undoubtedly the higher pressures will be most suitable with kerosene emulsion under practical conditions, mainly because of the increased speed of spraying and better coverage.

PRACTICAL TESTS.—The 10-per cent kerosene emulsion has been tried in tests in collaboration with the growers at several greenhouses in and near the District of Columbia, the spray being applied with a wheelbarrow type or motorized sprayer at 60 to 150 or 200 pounds' pressure. Applications were made on cloudy days or the late afternoon of bright days, followed by a thorough syringing with water the following morning. The effectiveness of the spray has depended largely on the thoroughness of the application. A considerable number of standard large-flowered chrysanthemums including Friendly Rival, Thanksgiving Pink, Woolfs' Pink, Indianola, Sun Gold, Edwin Seidewitz, Silver Sheen, R. M. Calkins, G. Pearson, October Rose, Charles Rager, Dr. Enguehard, Harvard, and others, as well as the pompon varieties Diana, Pink Dot, Dorothy Turner, and others, have been treated under greenhouse conditions without injury. At one greenhouse 4 applications at 4 to 9 day intervals were made. No foliage injury resulted, and the flowers bloomed satisfactorily. In one case where thorough syringing was not done the following morning injury to the young tender lateral buds and terminal leaves resulted. No spraying can be done when the flowers are in bloom, else injury will follow. The kerosene emulsion, or other effective spray, is especially useful where calcium cyanide fumigation cannot be practiced, as where there are mixed plantings some of which are sensitive to hydrocyanic acid gas. It was used in the fall of 1934 to control this mealybug on chrysanthemums growing out of doors under cloth shelters—a method now used by many growers for early flowering chrysanthemums. A block of 4 beds of chrysanthemums, each bed being approximately 150 by 5 feet and containing the pompon and button varieties—Greta, New York, C. P. Buhl, Baby, and Buckingham—were sprayed September 18 and 29, and October 1. The black chrysanthemum aphid (*Macrosiphoniella sanborni* Gill.) was also kept under control, and a good crop of flowers was cut.

UNPROMISING TREATMENTS.—Dipping infested plants in hot water at 110°F. for 15 minutes was quite ineffective, as was naphthalene fumigation at dosages of 2, 3, and 4 ounces per 1,000 cubic feet in overnight box treatments. With the latter method plant injury occurred at the higher dosages. A series of 4 consecutive fumigations with nicotine smudge in a tight fumigation box killed 17.9 per cent of 307 mealybugs and 26.8 per cent of 904 eggs. A tobacco powder guaranteed to contain 12.5 per cent of nicotine was used at the rate of ½ ounce of the powder to 1,000 cubic feet. Repeated fumigations carried on for 30 to 40 nights, as is sometimes done for chrysanthemum midge control, will probably give some reduction in mealybug infestation.

CALCIUM CYANIDE FUMIGATION.—The first tests with calcium cyanide (granular form, 40–50 per cent $Ca(CN)_2$) showed *P. gossypii* to be very sensitive to HCN gas. With the lower dosages and shorter exposures, considerable recovery took place after the first day, and experiments in-

dicated that mortality counts should not be made until the fourth or fifth day after fumigation. The eggs were removed shortly after fumigation so that subsequent hatching would not interfere with the counts. A series of preliminary fumigations indicated that high mortality (95–100 per cent) of the active stages of the mealybug could be obtained by overnight fumigations with low dosages of $Ca(CN)_2$ (⅛ oz. per 1,000 cu. ft.) in a tight fumigation box, but under practical greenhouse conditions this dosage would have to be increased to $\frac{3}{16}$ ounce or higher. Plant tolerance was good. High kills of the nymphs were obtained with low dosages in 1-hour box fumigations. A 4-hour greenhouse fumigation (6 p. m. to 10 p. m.) with a ⅜-ounce dosage gave 94 and 97 per cent kill of adults and nymphs, respectively, but short exposures have several disadvantages. There is some danger to the operator, especially during the night, in opening up a greenhouse when the HCN gas concentration is high, and also the higher dosages make an increase in expense.

Comparisons of the resistance of *Phenacoccus gossypii* with that of two other common greenhouse mealybugs, *Pseudococcus citri* and *P. maritimus*, have been made under various conditions, and the results are given in Table 2.

TABLE 2. COMPARISON OF *Phenacoccus gossypii* WITH *Pseudococcus citri* AND *P. maritimus* WITH REFERENCE TO THEIR RESISTANCE TO CALCIUM CYANIDE FUMIGATION[1]

Dosage per 1,000 cu. ft.	Temperature Start	Temperature End	Stage	*P. gossypii* Total number	*P. gossypii* Per cent killed	Compared species Total number	Compared species Per cent killed
	°F.					*P. citri*	
⅛ ounce[2]	72	63	Active[3]	1,412	99.3	597	52.5
			Eggs	284	98.9	581	49.8
¼ ounce[2]	72	63	Eggs	214	98.2	311	22.2
⅜ ounce[2]	72	63	Eggs	333	98.7	318	35.2
⅜ ounce[4]	74	76	Active[3]	553	73.0	231	3.5
						P. maritimus	
¼ ounce[4]	60	64	Active[3]	344	29.7	333	6.0
½ ounce[4]	60	68	Active[3]	2,123	99.8	370	8.9
Untreated checks			Active	1,518	0.4	571	1.0
						P. citri	
			Eggs	632	2.6	607	2.5
			Active	—	—	613	0.3

[1]Mortality counts made 4 or 5 days after fumigation.
[2]Fumigation made in a tight fumigation box; 17-hour exposure.
[3]Active stages include nymphs, pupae, and adults.
[4]Fumigation made in a loose greenhouse; 14-hour exposure.

It was evident that *P. gossypii* was much more susceptible (both as eggs and active stages) to HCN gas than either of the other two species of common mealybugs.

PRACTICAL TESTS.—Practical tests in cooperation with several growers in and near the District of Columbia were made in the fall of 1933, and throughout 1934. The results of a series of 3 fumigations made in the fall of 1933 in two heavily infested greenhouses are given in Table 3.

Excellent control of the mealybug was obtained, as can be seen, and no injury was done to the flowers in any stage of bloom or to the foliage. The fumigations in this case were started ½ to 1 hour after sunset, the heat was turned on, and a rising temperature (from 58°–70°F.) was maintained. Plants had not been watered for 12–24 hours before fumigation. Eggs exposed to the ½-ounce dosage gave a 90.5 per cent hatch

from 712 eggs. The data on egg hatching from some of the other fumigations were quite variable, and it was later found that the eggs are somewhat sensitive to temperatures of 40°F. and below, and this complicating factor was evidently present here in some cases.

TABLE 3. EFFECTIVENESS OF CALCIUM CYANIDE FUMIGATION[1]

Dosage per 1,000 cu. ft.	Stage	Greenhouse No. 1 Total number	Greenhouse No. 1 Per cent killed	Greenhouse No. 2 Total number	Greenhouse No. 2 Per cent killed
1/2 ounce	Adults	72	16.7	31	9.7
	Nymphs[2]	272	33.1	346	4.6
7/16 ounce	Adults	131	81.7	111	73.0
	Nymphs[2]	597	99.7	679	99.4
1/2 ounce	Adults	288	100.0	181	93.6
	Nymphs[2]	1,835	99.8	1,357	99.8
Untreated checks	Adults	164	2.4	192	1.0
	Nymphs[2]	1,358	0.4	1,229	0.0

[1]November 1933, time of fumigation was from 5:30 P.M. to 7 A.M., humidity at the start ranged from 50–65 per cent R. H., and temperature ranged from 58–70° F. rising from 2 to 8 degrees from start to finish. Greenhouse No. 2 was in all cases from 2–3 degrees cooler.
[2]Includes pupae.

All the varieties previously listed as tested with the kerosene emulsion sprays have been successfully fumigated in various stages of bloom at dosages sufficient to give a good kill of the active stages of the mealybug (as high as ½ oz. per 1,000 cu. ft. in some cases). In addition to these the following have also been treated safely: Sun Glow, Will Rogers, Betsy Ross, Secretary Hyde, Citronella, M. de Petris, Secretary Meredith, Gold Lode, Honeydew, Amarita, Rose Perfection, Golden Glory, Rose Charm (pompon), and the singles Yellow Godfrey and Mrs. Godfrey. In one case some injury to the petals of October Rose followed calcium cyanide fumigation, but on examination and further tests it was found that the red spider mite and some thrips feeding scars were present, which in combination with the HCN were evidently responsible for injury.

The stock plants are evidently no more sensitive to cyanide injury than the fast-growing young plants; and a number of different varieties have been fumigated safely, as have young chrysanthemum cuttings, both rooted and unrooted.

In some practical tests on the value of nightly fumigations with calcium cyanide for controlling the chrysanthemum midge on rooted and unrooted cuttings, it was found that this practice also controlled the Mexican mealybug. A dosage of 2/5 ounce per 1,000 cubic feet in a loosely constructed greenhouse gave over 99 per cent kill of the active mealybugs and as high as 100 per cent kill of the eggs in two test series of 4 and 5 consecutive over-night fumigations (11:30 P. M. to 5:30 A. M.). When the entire treatment of 40 or more consecutive nightly fumigations is given, complete control should be obtained. Little or no foliage injury occurred to a large variety of chrysanthemum cuttings, including Celestra, Chattanooga, December Glory, Distinction, Friendly Rival, Golden October, Gold Lode, Justrite, Mrs. Kidder, N. T. Ross, and Silver Sheen, as well as a wide variety of pompons given this 40-night treatment.

During the midsummer and fall of 1934, 37 practical fumigations of infested chrysanthemum plants were made on the growing crop in co-

operation with the growers at seven different greenhouses. Mortality counts of the active and egg stages were made in the majority of cases, but the data cannot be given for lack of space. Dosages of $\frac{3}{16}$ ounce per 1,000 cubic feet were first used and these gradually increased until a kill of 95 per cent or more of the active stages resulted. These effective dosages killed 5 to 15 per cent of the eggs but rarely more when the correct conditions for effective fumigation were maintained. The effective dose of course varied with each greenhouse, depending upon the tightness and ranged from $\frac{3}{16}$ to $\frac{5}{8}$ ounce with an average of 6/16 ounce. A total of 3 weekly fumigations brought the mealybug under control, but there were always a few survivors, thus making 2 or 3 more fumigations advisable. Some growers have adopted a regular 7- to 10-day schedule of repeated light dosages as an "insurance" measure. Under summer and early fall conditions, the experiments indicate that the fumigation should be started late in the evening at 10 to 11 P. M. (2 to 3 hours after sunset) and the houses ventilated early the next morning before the bright rays of the sun reach them. Where these conditions were not carefully observed foliage injury occurred. The plants should not be watered for 12–24 hours before fumigation.

When the temperature was over 72°F. at the start of the fumigation with indications of going higher, some foliage injury resulted, and the general rule was adopted of using a slightly lower dosage in such cases. With the higher temperatures an increase in kill of the active stages and the eggs was obtained, but when the temperature was below 55°F. (as may happen occasionally early in the fall before the heating plant is in operation) a considerably lower kill was obtained. It seems best, then, to fumigate only on nights with temperatures above 55°F. or to turn the heat on just before starting fumigation so that a rising temperature is maintained. This will prevent condensation of moisture and increase the effectiveness.

Varieties Sensitive to Hydrocyanic Acid Gas.—One variety of pompon chrysanthemum (Mrs. Calvin Coolidge?) could not be fumigated at any effective dosage without slight injury, but no others were found which in any way approached its susceptibility. In general the tolerance of the many varieties tested has been good, but several, such as Dr. Enguehard (of the standard large-flowered type), must be fumigated with care. G. Pearson, Betsy Ross (standard), and the pompon Chicago Pearl are also slightly sensitive where the correct conditions are not maintained. A large number of pompon, anemone, and single varieties have been fumigated without injury.

Summary.—The Mexican mealybug has become widely dispersed in the United States, being particularly injurious to greenhouse chrysanthemums, where it is responsible for losses as high as 50 per cent of the crop. Derris, pyrethrum, and tobacco dusts were ineffective for control. Sulphur dusts showed some promise, killing high percentages of the eggs. Various sprays at the concentrations tested differed in the following order from lesser to greater effectiveness: (1) Soap, (2) nicotine, (3) pyrethrum or derris, (4) organic thiocyanates, (5) 10-per cent kerosene emulsion. Lauryl and other thiocyanates killed a high percentage of

eggs and exerted a residual toxic action for several days after spraying. Ordinary kerosene (43.4° Bé.) was more effective than a highly refined lighter-gravity kerosene (48.6° Bé.). The effectiveness of 5- or 10-per cent kerosene emulsion did not differ much at 25, 100, 200, or 300 pounds' pressure. Practical tests showed the 10-per cent kerosene emulsion to be effective, and it was tolerated by a wide variety of chrysanthemums when applied as recommended. Hot-water dips and naphthalene or nicotine fumigations showed little promise. *Phenacoccus gossypii* was much more susceptible to calcium cyanide fumigation than *Pseudococcus citri* or *P. maritimus*. Overnight exposures to dosages of $\frac{3}{16}$ to $\frac{5}{8}$ ounce per 1,000 cubic feet (depending on tightness of the greenhouse)gave high mortality and killed from 5 to 15 per cent of the eggs. Three to six fumigations at weekly intervals gave good control. The stock plants, unrooted and rooted cuttings, growing plants, and plants in bloom of a wide variety of chrysanthemums have been fumigated safely where the recommended conditions have been maintained. Calcium cyanide fumigation is of course much more suitable from the standpoint of thoroughness, efficiency, cost, and ease of application than an effective spray.

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EXPERIMENTS IN THE CONTROL OF TWO GREENHOUSE MEALYBUGS, *PHENACOCCUS GOSSPYII* T. & CKLL. AND *PSEUDOCOCCUS CITRI* RISSO

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During the fall of 1933 serious injury occurred on greenhouse chrysanthemums in Ohio as a result of the attack of the Mexican mealybug, *Phenacoccus gossypii* T. & Ckll. The injury was widespread over the State and in some greenhouses considerable portions of the crop were lost. As a result of the demand for information, experimental work was started in an effort to obtain a satisfactory insecticidal control for this species.

In the early or preliminary experimental work, in which many commercial insecticides were tried, the socalled bottle-plate method was used; that is, the infested leaf or twig to be used in any experimental

unit was inserted at the stem end into a small bottle containing water. The bottle was then set in the middle of a plate around the margin of which was placed a ring of tanglefoot. The experiments were set up on a laboratory table usually with four or five replications for each treatment, the experimental units being arranged in blocks and the treatments distributed at random within the blocks. The spraying was done with a small hand sprayer. These experiments were conducted at a temperature fluctuating around 70°, with the relative humidity varying between 30 and 40 per cent.

The mortality record was taken between 24 and 48 hours after the experiment was started. The results of one of the early experiments are given in Table 1.

TABLE 1. MORTALITY RECORD OF *Phenacoccus gossypii* T. & CKLL. FROM VARIOUS INSECTICIDES

Treatment		Replicate number 1	2	3	4	5	Mean
Lethane No. 420	1–400						
Penetrol	1–200	100	65	100	92	100	91
Lethane No. 420	1–400						
Soap	*1–250	85	65	81	100	90	84
Nicotine Sulfate	1–400						
Soap	1–250	31	74	68	65	85	65
Rotenone (1 per cent)	1–200						
Penetrol	1–200	32	21	13	31	60	31
Verdol	1–100	34	7	17	19	28	21
Check		0	4	5	0	0	2

*The soap used in this and all other experiments was a 40 per cent liquid potassium oleate. Dilutions were made on the basis of the actual soap content; thus, 1–250 means that 1 gallon (liquid measure) of soap was used with 100 gallons of water.

As a result of this experiment and others of a similar nature, it seemed that Lethane No. 420, an aliphatic thiocyanate, was significantly superior to all other insecticides used. Accordingly, an experiment using Lethane with Penetrol and with soap was set up in a commercial house. A single row across the bed was used as a plot and each treatment was replicated five times. Since closely planted check rows were interspersed with treated rows and thus furnished a continuous source of reinfestation, all plots were treated at weekly intervals until blooming time, a period of 5 weeks. At the close of this period, a single-leaf sample was taken from each plant of all plots, there being approximately 25 samples for each treatment, and all the live insects on the leaf were counted. Table 2 shows the population record for the different treatments.

TABLE 2. POPULATION RECORD AFTER FIVE SPRAY APPLICATIONS ON CHRYSANTHEMUM IN COMMERCIAL HOUSE

Treatment		Replicate number 1	2	3	4	5	Per cent reduction from check
Lethane No. 240	1–400						
Penetrol	1–200	13	5	1	5	22	99.1
Lethane No. 420	1–400						
Soap	1–250	44	8	18	0	0	98.6
Lethane No. 420	1–800						
Penetrol	1–200	35	103	46	0	1	96.3
Check		1691	1223	842	571	718	—

As shown in Table 2, each of the three treatments was commercially effective in controlling the species, although live insects could be found

FIG. 56. Sprayed five times with Lethane No. 420 1–400 Soap 1–250.

FIG. 57. Check—no spray.

in all plots. Photographs of two demonstration plots which were treated the same as those in the experimental block are shown in Figures 56 and 57.

As a further test of this material five beds in a commercial greenhouse containing different varieties of chrysanthemums, some of which were severely infested with mealybugs, were sprayed with Lethane No. 420 at a dilution of 1 part to 400 combined with Penetrol at 1 to 200. The spray was applied with an orchard sprayer yielding 300 pounds pressure. No mortality record was taken as a result of this spray application; however, it was the opinion of the grower as well as that of the writer that the crop was saved by the treatment.

In this commercial application some of the varieties showed slight burning. This may have been due more to physical effects of the spray than to chemical injury, since the crowded condition of the plants and the intermingling of the foliage from adjacent rows caused some plants to receive a more driving spray than was desired. At any rate no insecticidal injury to the foliage was observed in any of the other tests when the same dilution of the insecticide was used and a different type of sprayer was employed.

Subsequent experiments were conducted in the greenhouse in an attempt to lower the concentration of materials in order to decrease the cost of treatment, as well as to reduce the possibility of injury to plants. In these tests a knapsack sprayer was used on growing plants on which a severe infestation had been imposed some time previously. A summation of the results from the various treatments is given in Table 3.

TABLE 3. SUMMATION OF THE RESULTS FROM LETHANE NO. 420 TREATMENTS ON *Phenacoccus gossypii* T. & CKLL.

Treatments		Number of Expts.	Number of Reps.	Sprays applied	Mean per cent mortality
Lethane No. 420	1–400				
Penetrol	1–200	5	26	1	94
Lethane No. 420	1–400				
Soap	1–250	7	30	1	90
Lethane No. 420	1–400				
Penetrol	1–400	2	10	1	92
Lethane No. 420	1–400				
Soap	1–500	2	10	1	92
Lethane No. 420	1–800				
Penetrol	1–200	4	21	1	92
Lethane No. 420	1–800				
Soap	1–250	1	5	1	94
Lethane No. 420	1–800				
Penetrol	1–200	3	9	2	97
Lethane No. 420	1–800				
Soap	1–250	2	7	2	92
Lethane No. 420	1–800				
Penetrol	1–500	1	3	2	95
Check		6	33	0	3

It may be noted from Table 3 that the mortality was not materially reduced when the concentration of the insecticide was decreased 50 per cent or when the spreader was decreased a like amount. In this connection it may be noted that Murphy and Peet[1], in working with

[1]Murphy, D. F., and Peet, C. H., Industrial and Engineering Chemistry, Vol. 25, No. 6, 1933.

Pseudococcus citri Risso, obtained a mortality of approximately 96 per-cent when Lethane No. 420 was used at the rate of one part in 800 with Penetrol at 1 to 200 and a 95 per cent mortality when the insecticide at the same strength was used with Penetrol at one part to 1000.

In an ovicidal test conducted on the eggs of *Phenacoccus gossypii* T. & Ckll. enclosed within the ovisac, Lethane No. 420 was again found to be effective. Eight egg clusters in various stages of development were used in each replication of all treatments. The results are given in Table 4.

TABLE 4. RECORD OF HATCH OF EGGS OF *Phenacoccus gossypii* T. & CKLL. AFTER INSECTICIDE TREATMENT

Treatments		Replicate number 1	2	3	4	Per cent reduced from check
Lethane No. 420	1–400					
Penetrol	1–200	1	34	15	17	98
Lethane No. 420	1–400					
Soap	1–250	36	61	63	89	93
Lethane No. 420	1–800					
Penetrol	1–200	12	5	9	16	99
Check		895	1071	567	794	—

Following the effective use of Lethane No. 420 on the Mexican mealy-bug, a test of this material and of two other materials was made on the greenhouse mealybug, *Pseudococcus citri* Risso, infesting Coleus. Three applications were made at intervals of one week, after which population records were taken on leaves selected at random from all plants.

TABLE 5. LIVE POPULATION RECORD IN INSECTICIDE TEST ON *Pseudococcus citri* RISSO

Treatments		Replicate number 1	2	3	4	Total live	Per cent reduced from check
Lethane No. 420	1–800						
Soap	1–250	0	10	1	2	13	99
Nicotine Sulfate	1–400						
Verdol	1–200	0	7	1	1	9	99
Rotenone-Pyrethrum spray[1]	1–200	55	158	62	95	370	74
Check		505	552	241	134	1432	—

[1]A commercial product containing 0.75 per cent Rotenone and 1.8 per cent Pyrethrins.

In this experiment, Lethane No. 420 at a 1–800 dilution, when used with soap, gave practically the same kill as did nicotine sulfate at 1 part to 400 when used with Verdol at 1 to 200. Throughout the experiments with the Mexican mealybug, however, the nicotine sulfate-Verdol combination, at the dilution given above, was considerably inferior in effectiveness to Lethane No. 420 when the Lethane was used at twice the dilution of the nicotine.

DR. J. M. GINSBERG: I would like to mention that the same species of insect, mealybugs, on the same plant was controlled with one application of a highly refined, light petroleum oil. The chrysanthemum plant is very resistant against injury from this oil so that the owner of the greenhouse where the experiments were conducted consented to dip

all his plants, and he has done it for the last three years successfully. He dips all his chrysanthemum plants directly into the oil before transplanting into the beds. That is done when the plants are young and while in the pot. One application killed adults, nymphs and eggs.

His expenses show that this was the cheapest method of controlling the mealybug on the chrysanthemum.

Section B, Silver Room, December 29, 1934

CHINCH BUG BARRIERS AND REPELLENTS

By W. P. Flint, M. D. Farrar and W. E. McCauley

History.—Barriers have been used for more than 70 years to prevent the migration of chinch bugs from small grains to corn. Dust barriers were used prior to 1860. In 1864 a Rockford, Illinois, Newspaper published a report of the use of boards set on edge in the ground and wet with kerosene as an effective method of stopping migration of the chinch bug. In the same year "The Illinois Farmer" mentions the use of coal tar treated boards in Wisconsin for the same purpose. Coal tar barriers were in common use in parts of Illinois by 1871. The first use of creosote barriers, in so far as known, was in Illinois in 1913.

Testing of Barriers.—The most practical method for the evaluation of either barrier mechanics or chinch bug repellence of materials is under field conditions. Here the bugs respond normally to changes in the weather, food supply, etc. At the same time the barriers are subjected to those climatic factors such as rain, wind, dust and heat, all of which play a part in barrier efficiency. Linear tests of materials along the sides of a field are not satisfactory because of the erratic movement of migrating bugs.

To approach normal field conditions, plots one rod square were constructed in stubble fields after the grain had been removed. Test barriers were laid on the sides of these rod square plots. Two materials on the two sides of each plot were tested. In replicated plots the directional position of each material was reversed, thereby exposing each barrier or repellent in all directions to chinch bug migration. A small pile of cut corn stalks in the center of each afforded some food and protection to confined bugs during unfavorable weather.

Collections of young bugs were added daily to all plots, maintaining about one-half pint (minimum 130,000) of bugs within the plot at all times.

Observations were made from 10 A. M. to 5 P. M. on the side of the plots showing the most bugs. Two feet of barrier line was observed for three minutes, the number of bugs crossing constituting one unit of efficiency.

Mechanical Barriers.—Successful mechanical barriers of metal or paper are shown in Figure 58. All required creosote or other repellent to maintain their efficiency. Barriers 1–5 were all very efficient. (Table

2, Items 1–4.) They have high initial cost but require less attention. Barriers 6, 7 are impractical, while 8, 9, offer promise as the most practical solution of a combined mechanical-repellent barrier. Barriers 8, 9, are easily and rapidly installed, withstand weathering and require only a minimum of attention. Either tar paper or corrugated paper should be cut 4 inches wide and dipped in the repellent before erection. With corrugated paper the corrugations should stand vertical to the soil.

TABLE 1. VISCOSITIES OF CERTAIN COMMERCIAL AND EXPERIMENTAL CREOSOTES USED IN ILLINOIS IN 1934, INDICATING THE SATISFACTORY RANGE OF VISCOSITY

Item No.	Manufacturer	Source		Viscosity seconds Saybolt 100°F.	Relation between viscosity and application of barrier line
		Sample	No.		
1.....	Inland Tar & Acid Co.	Car	2	46	Satisfactory
2.....	Reilly Tar & Chemical Co.	Car	2	47–55	Satisfactory
3.....	Koppers Products Co.	Car	2	48–50	Satisfactory
4.....	Barrett Co.	Car	2	90–95	Too heavy
5.....	Local supplies	Car	2	Semi-fluid	Much too heavy
6.....	Reilly Tar & Chemical Co.	Experimental	1	32	Too light
7.....	Pittsburgh Coal Carbonization Co.	Experimental	1	42	Satisfactory
8.....	Reilly Tar & Chemical Co.	Experimental	1	47	Satisfactory
9.....	Ruberoid Co.	Experimental	1	90	Too heavy

EARTHEN BARRIERS.—Under practical field conditions barriers (ridges) constructed out of the earth around the fields have many advantages. Their entire cost of construction is labor, as the required tools are available on all farms. Experimental and field tests have shown well constructed and maintained barriers of this type to be efficient and dependable under most conditions. Earthen barriers sometimes fail when high winds carry the bugs across the creosote line.

REPELLENT MATERIALS.—Chinch bugs are strongly repelled by the odors from crude naphthalene or creosote. The efficiency of all repellents depends almost entirely on their power of emitting these odors. Creosotes with viscosities of 90 seconds or greater at 100° F. Saybolt test tend to dry on the surface during exposure. This dry surface film apparently reduces the volitation of repellent odors from the creosote. The too-heavy oils, although relatively efficient in repelling chinch bugs, are so viscous that they tend to run downward from the repellent line during applications. These streaks of oil, at right angles to the line, confuse the bugs and reduce the efficiency of the line.

Oils below 42 seconds Saybolt, 100° F. are not as efficient as oils between 42–90 seconds over periods of more than 24 hours between renewals. The lighter bodied oils apparently penetrate the soil too rapidly or are volatilized by soil temperatures. Table 1 shows the viscosities of several creosotes widely used in 1933. Oils classified as too light, penetrated the soil and lost their efficiency within 24 hours. An oil with a viscosity of between 45 and 65 seconds viscosity, 100° F. should, at summer temperatures, flow freely to form a line of uniform width without splash or run-down.

Materials found unsatisfactory for chinch bug repellents include:

Ground chalk "Marle"
Dusting sulphur
Highly aromatic petroleum oils
High viscosity pine tar, and
High viscosity creosotes.

Materials losing their value after the first day are:

Naphthalene drain oil
Illinois No. 3
Turpentine.

Oils of value one or two days are:

Pine tar
Pine tar in sawdust
Pine wood creosote
Coal tar neutral (Reilly No. 3).

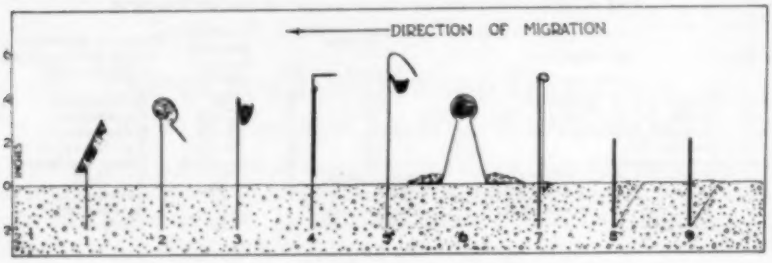

FIG. 58.—Diagram of mechanical-chemical barriers in cross section. One and 2—metal with saturated felt wick; 3—metal with saturated earth in the trough; 4—metal with a saturated burlap face; 5—metal with free oil in the trough; 6—saturated felt with saturated felt wick; 7—saturated tar or heavy paper supported by wire; 8—saturated tar paper set 2 inches into the soil; 9—saturated single faced corrugated paper set 2 inches into soil.

Table 2 summarizes the results with types of barriers and repellent materials. Several types of metal barriers were found satisfactory. All

TABLE 2. RESULTS OF BARRIER AND REPELLENT TESTS

Item No.	Type of barrier	Repellent	Hours since repellent was renewed: Numbers of observations 24	48	72	96	Total records	Ave. No. bugs across 100 ft.—1 Min. 24	48	72	96	Average for 96 hours
1	Metal	Groove filled with liquid	1	2	1	1	5	0	0	0	0	0
2	Metal	Saturated felt wick	4	6	4	1	15	0	2	0	0	1
3	Metal	Groove filled saturated earth	9	6	3	3	21	1	8	12	125	22
4	Metal	Saturated burlap face	12	7	4	4	27	17	9	10	83	24
5	Tar paper	Reilly No. 4	3	5	5	3	16	0	36	20	10	26
6	Tar paper	Barrett 80–20	2	4	3	2	11	17	42	160	110	81
7	Tar paper	Colledge pine tar	2	3	3	2	10	0	127	300	183	165
8	Corrugated paper	Reilly No. 4	2	6	3	2	13	0	14	0	25	13
9	Corrugated paper	Barrett 80–20	2	2	4	2	10	16	8	220	342	161
10	Corrugated paper	Colledge pine tar	3	4	7	4	18	133	350	530	785	480
11	Ridge of earth	Pittsburgh coal carbonization Co. No. 2	—	3	–	1	4	—	0	—	0	0
12	Ridge of earth	Koppers neutral hydro carbon	5	4	4	1	14	0	7	11	13	6
13	Ridge of earth	Ill. No. 1	29	14	1	1	45	5	47	0	107	20
14	Ridge of earth	Standard tar prod. Ill. No. 2	—	2	1	1	4	—	8	16	117	37
15	Ridge of earth	Lewis Ill. No. 2	13	7	1	1	22	9	96	0	53	38
16	Ridge of earth	Reilly Ill. No. 2	2	3	2	2	9	17	39	17	133	50
17	Ridge of earth	Reilly No. 4	1	1	2	3	7	67	50	33	87	63
18	Ridge of earth	Barrett 80–20	2	4	4	3	13	116	17	54	111	65
19	Ridge of earth	Barrett No. 70	2	1	–	4	7	75	33	—	87	76
20	Ridge of earth	Ruberoid Ill. No. 2	—	1	–	2	3	—	0	—	142	95
21	Ridge of earth	Reilly No. 5	2	1	2	3	8	33	116	50	183	104
22	Ridge of earth	Barrett 60–40	2	1	1	5	9	25	50	100	213	140

required a method of maintaining a repellent line such as free oil, saturated burlap, earth or felt. These had to be re-treated at least every 7 days except Item 1. Figure 58 shows in cross section the mechanical ideas involved in these barriers. All metal barriers have high original cost ($.10 per rod) but require less attention and repellent material.

The most promising low cost mechanical barriers are tar paper, Items 5, 6, 7, and single faced corrugated paper, Items 8, 9, 10, each cut 4 inches wide. When saturated with repellent and set 2 inches into the soil, a line of these materials can be rapidly established. (Harris, and Decker, 1934.) Both of these barriers required occasional renewal of the repellent. The efficiency of repellents tested on paper barriers was:

(1) A creosote meeting Illinois Specification No. 2 but of higher viscosity.
(2) A mixture of 80 per cent creosote and 20 per cent coal tar.
(3) Chinch bug pine tar.

Of Items 11 to 22, oils tested on a ridge of earth, Items 11, 14, 15, 16, 20, are various manufacturers oils meeting Illinois Specification No. 2, (Flint, et al, 1934). Items 12, 13 are or approach Illinois Specification No. 1, (Flint, et al, 1934). Both have high naphthalene content. Items 17 to 22 are all of higher viscosity than Illinois Specification No. 2 and certain oils had the creosote content reduced by the addition of coal tar. Of the materials tested, Illinois Specification No. 2 is the superior product. For best results the viscosity range should be between 45 and 65 seconds Saybolt test at 100° F.

SPECIFICATIONS

(1) Illinois No. 1
"A coal tar distillate obtained by draining oil from either crude naphthalene or thoroly distilled napththalene oil. It shall contain not more than 2 per cent water and shall be free from crystals at 25° C. Specific gravity at 15.5° C. shall be within the limits of 1.01 and 1.04."
(Per cent tar acids, not less than 6.) (Viscosity 45–65 seconds 100° F. Saybolt test.)

(2) Illinois No. 2.
"The oil shall be a distillate of coal-tar or coke-oven tar. It shall not contain more than 3 per cent of water, nor more than 0.5 per cent of matter insoluble in benzol. The specific gravity of the oil at 38° compared with water at 15.5° C. shall be not less than 1.03.
"The distillate based on water-free oil, shall be within the following limits:
"Up to 210° C. not more than 5 per cent.
"Up to 235° C. not more than 25 per cent.
"The residue above 355° C., if it exceeds 5 per cent, shall have a float test of not more than 50 seconds at 70° C. The oil shall yield not more than 2 per cent coke residue.
"The above test shall be made in accordance with the standard methods of American Wood Preservers' Association."
(Viscosity 45–65 seconds at 100° F. Saybolt test.)

(3) Barrett
No. 70—Heavy creosote oil.
80–20—80 parts creosote oil and 20 parts coal tar solution.
60–40—60 parts creosote oil and 40 parts coal tar solution.

(4) Colledge
"Pine Tar". This was a straight pine tar fraction prepared for a chinch bug barrier repellent.

(5) Koppers
"Coal tar neutral". A neutral coal tar oil with a considerable quantity of the naphthalene fraction.

(6) Pittsburgh Coal Carbonization Co.
No. 2 oil is a distillate of tar obtained by a low temperature carbonization of coal. Not less than 30 per cent of the oil is soluble in 10 per cent caustic soda solution. Not less than 15 per cent distills below 210° C. and not less than 85 per cent distills below 355° C. using A.S.T.M. Method D 246.

(7) Reilly
No. 3 Coal tar neutral oil. This product contains very little naphthalene and has had the acid extracted; it is also in a lighter body than Reilly Illinois No. 2. (Viscosity 32 seconds Saybolt, 100°F.)

(8) Reilly
No. 4 represents an oil meeting Illinois No. 2 specifications but is very much heavier body than Reilly Illinois No. 2.

(9) Reilly
No. 5. A very heavy straight creosote oil unsuitable for ordinary wood-preserving work.

ACKNOWLEDGMENTS

Assistance in this project was given by the Department of Agricultural Engineering, Ill. Agricultural Experiment Station, Urbana, Ill. and by Thayer Cleaver, Agricultural Engineer, U. S. Dept. of Agriculture, Urbana, Ill.

The following manufacturers furnished materials for tests:

1. Barrett Co., New York, N. Y.
2. E. W. Colledge Co., Chicago.
3. Inland Tar & Acid Co., Chicago, Ill.
4. Koppers Products Co., Pittsburgh, Pa.
5. Lewis Tar Products Co., Lyons, Ill.
6. Pittsburgh Coal Carbonization Co., Pittsburgh, Pa.
7. Reilly Tar & Chemical Corp., Chicago, Ill.
8. Ruberoid Mills, Chicago, Ill.
9. Standard Tar Products Co., Milwaukee, Wis.
10. Standard Oil Co., Chicago, Ill.
11. Shell Petroleum Corp., (Shell Chemical Co., Pittsburg, Cal.; Shell Development Co., Emeryville, Cal.)

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A COMPARISON OF CERTAIN MATERIALS USED AS CHINCH BUG BARRIERS

By L. L. HUBER and J. S. HOUSER, *Ohio Agricultural Experiment Station*

The purpose of this investigation was to compare the effectiveness of certain materials used by, or recommended to, farmers as chinch bug barriers in 1934. These materials were as follows: No. 1, water gas tar, specific gravity at 60°F., 1.132, obtained from artificial gas plant, Bellefontaine, Ohio; No. 2, water gas tar, specific gravity at 60°F., 1.060, ob-

tained from artificial gas plant, Van Wert, Ohio; No. 3, Tarvia M. T., specific gravity at 60°F., 1.1174, obtained from the Barrett Company, Cleveland; and No. 4, wood preserving creosote, specific gravity at 60°F., 1.074, obtained from Orrville Wood Preserving Company, Orrville, Ohio.

This experiment was conducted under normal field conditions. Chinch bugs were migrating directly north to a field of oats from a moderately infested wheat field, which in early June averaged five bugs per linear foot of wheat. A furrow was plowed and prepared, and the materials were applied in the standard and accepted manner (1). The four treatments were arranged in randomized blocks with eight replications, each treatment being 16 feet in length. The width of the barrier line was uniform for all treatments. Four feet beyond the experimental barriers, Material No. 4 was applied to protect the oats from bugs crossing ineffective barrier materials. Additional lines, placed at right angles to this second line of defense, extended backward between the treatments of the experimental line. These were to prevent bugs which were stopped by, or which crossed the line of, any given treatment from confusing the record of performance of adjoining treatments. Details of the arrangement of treatments are shown in Figure 59.

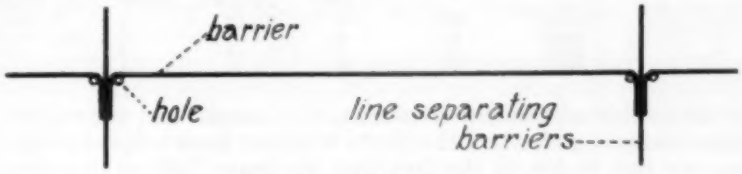

FIG. 59.—Chinch bug barrier

The treatments were applied on June 30 and all except No. 4 were renewed each day. It was not necessary to renew No. 4 before July 4. On July 3, before the treatments had been renewed, estimates of the number of bugs in front of the barriers were made by counting and estimating the bugs in five random places along the line and not more than 2 inches behind it. A similar record taken on July 6 was averaged with the first. The average of these two estimates is recorded in Table 1.

TABLE 1. SHOWING THE NUMBER OF CHINCH BUGS IN FRONT OF BARRIERS

Treatments	Replicates							
	A	B	C	D	E	F	G	H
No. 1	978	11492	5379	5379	2690	9291	4157	6357
No. 2	489	2890	10269	8558	8747	11981	10758	11492
No. 3	734	2201	2690	4157	4401	5624	3912	3179
No. 4	3423	10514	12714	11981	6602	16382	12959	9291

To determine the percentage of bugs crossing the barriers, counts were made on July 3 and July 6 of the total number of bugs crossing two random sections of each replicate of each treatment in 1 minute. From these two samples was estimated the total number of bugs crossing each barrier. The estimates obtained on the two above dates were averaged. These data are recorded in Table 2. The percentage of the bugs which crossed the barriers is indicated in Table 3.

TABLE 2. SHOWING NUMBER OF CHINCH BUGS CROSSING EACH BARRIER MATERIAL IN ONE MINUTE

Treatments	Replicates A	B	C	D	E	F	G	H
No. 1	381	257	374	779	466	379	366	554
No. 2	57	61	79	118	61	100	79	61
No. 3	322	235	331	918	570	923	670	431
No. 4	26	27	57	35	92	135	70	105

TABLE 3. SHOWING PERCENTAGE OF BUGS CROSSING BARRIERS

Treatments	Replicates A	B	C	D	E	F	G	H	Av.
No. 1	28.1	2.2	6.5	12.7	14.8	3.9	8.1	8.0	10.6
No. 2	10.4	2.1	0.8	1.4	0.7	0.8	0.7	0.5	2.2
No. 3	30.4	9.7	11.0	18.1	11.5	14.1	14.6	11.9	15.2
No. 4	0.8	0.3	0.4	0.3	1.4	0.8	0.5	1.1	0.7

The practical value of any insecticide is measured, of course, not only in terms of actual efficiency but also in terms of cost. The data recorded in Table 4 show the comparative cost of the four materials tested.

TABLE 4. SHOWING LENGTH OF BARRIER LINE ONE INCH WIDE (FEET PER GALLON OF MATERIAL) AND RELATIVE COST OF BARRIERS

Treatments	No. of ft. per gallon	Ratio of ft. per gallon	Actual cost per gallon in cents	Cost on basis of ratio of ft. per gal. in cents	Relative rate of renewal of applications	Cost on basis of renewal and on ft. per gal.
4	1110.0	100	50	50	1	$0.50
2	916.0	83	5	6	4	0.24
1	571.0	51	8	16	4	0.64
3	432.0	39	18	46	4	1.84

As far as this experiment is concerned, it seems that present recommendations may go beyond the limits of actual knowledge. Perhaps the reason for this is due to the fact that the magnitude of experimental error involved in field experiments is a question that has not received as much recognition in chinch bug experimentation as its importance justifies.

An analysis (2) of the data recorded in Table 3 will show no significant difference between No. 2 and No. 4 or between No. 1 and No. 3. Moreover, reference to Table 4 will indicate that No. 1 and No. 3, even though they had been as effective as No. 2 and No. 4, would have cost considerably more than the other two materials. Attention is called to the fact that the data point to a real difference between No. 1 and No. 2, both of which are water gas tars. Although the evidence in this experiment points to the superiority of No. 2, it is by no means certain that another sample from the same source would give equally efficient protection; for, according to chemists, these by-products of artificial gas plants are too variable to merit any considerable degree of reliance, as far as repellency is concerned. This is to say that another sample from each of the gas plants might have given entirely different results. Such an assertion, of course, needs investigation in the field.

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THE ALFALFA SNOUT BEETLE, *BRACHYRHINUS LIGUSTICI* L., A NEW INSECT PEST IN NEW YORK STATE

By P. W. CLAASSEN and C. E. PALM

The alfalfa snout beetle, *Brachyrhinus ligustici* L., a serious pest of alfalfa and clover in Europe, has recently become established in New York State in the vicinity of Oswego and bordering areas along the southern and eastern shores of Lake Ontario.

Since this new pest already has completely destroyed entire alfalfa fields on several farms and caused severe injury to many other fields its presence in New York State is looked upon with great concern.

Although it was not until the fall of 1933 that this insect was definitely connected with its depredations to alfalfa, growers in the vicinity of Oswego, New York, say that they have noticed their alfalfa dying out in spots for some years. They, however, attributed this loss of stand to sour spots in the soil, drouth or other environmental conditions.

A preliminary survey in the fall of 1933 indicated that the alfalfa snout beetle had become permanently established over an area of approximately 40 square miles in the immediate vicinity of Oswego, but more careful scouting during the past season shows that the infestation extends eastward along the lake shore as far as Sacketts Harbor or a distance of some 50 miles.

Last spring the New York State Legislature appropriated a small sum of money for the investigation of this pest and during the past season we have learned a great deal about the life history and behavior of this insect, and we have been getting a few leads on possible measures of control.

During part of the summer the Bureau of Entomology cooperated with us in this work, particularly in the scouting, whereby the present known distribution of this beetle in New York State was established.

DISTRIBUTION.—The alfalfa snout beetle is generally distributed throughout northern and central Europe. Eastward it extends through Russia into Siberia; northward into Sweden; westward into England and Scotland and southward as far as Italy.

LIFE HISTORY AND BEHAVIOR.—The main damage to alfalfa is done by the larvae or grubs which feed on the roots of the plants, cutting off the side roots, girdling the main tap roots and finally cutting them off entirely. This kills the plants or weakens them so that they are unable to continue growth.

The adult beetles are dark greyish-black, about half an inch in length and the head is prolonged into a broad snout. The beetle has a two-year life cycle and there are indications that under certain conditions they may require three years to complete their development.

In spring the adults emerge from the ground where they have remained inactive in their resting cells since transformation from the pupal stage the previous summer. In Russia Wassiliew reports that the beetles appear in March or April. The first adults, during the past season, were seen on May 9 and on August 21 one live female was found which still had a few eggs in the ovaries.

Since this species is parthenogenetic every adult which emerges is capable of laying eggs and during the past season the number of eggs laid per female varied from 125 to 515 with an average of 336 eggs per beetle. The fact that this insect is parthenogenetic is a very important factor in the spread of this species to new fields since every single specimen is capable of starting a new infestation. Fortunately the adults cannot fly for the hind wings are not developed and the wing covers are sealed on top of the body. However, the beetles are good crawlers and are capable of traveling considerable distances on foot.

On first appearance the adults are sluggish and seek shelter under stones and plants. Soon, however, they start in search of food and they feed voraciously on various plants. We have observed them feeding on alfalfa, red clover, white and yellow sweet clover, rhubarb, strawberry, raspberry, grapes, apple, asparagus and other plants. In some fields rhubarb, strawberries and raspberries were completely defoliated by the beetles. One strawberry plant harbored 30 adults, one rhubarb 160 and single alfalfa plants as many as 25 beetles. The adults may thus become extremely destructive at this time of emergence.

After feeding the adults begin their migration in search of favorable host plants around which to deposit their eggs. Enormous numbers of the beetles were observed traveling across fields and roadways. In a trench barrier not over 250 yards in length some 30,000 beetles were caught.

After migration ceases the beetles deposit their eggs around the bases of the alfalfa plants in the upper two inches of soil. Forty beetles caged separately laid a total of 13,427 eggs, the total number per beetle ranging from 125 to 515 with an average of 335.5. One female deposited 98 eggs in a single day. The egg-laying period for the 40 individuals lasted 38.7 days and the average number of eggs laid per beetle per day over this period was 7.230. The first eggs were deposited on May 31 and the last ones on July 20. The average length of life of the beetles from the time they began to deposit eggs until they died was 48.9 days, indicating that they live about ten days after oviposition stops.

Of 8976 eggs kept under observation in the field laboratory 5359 or approximately 60 per cent hatched. The average incubation period at temperatures fluctuating between 68 and 75 degrees Fahrenheit varied from 15 to 22 days with 10 to 12 days for a minimum and 25 days for maximum period of development. Under field conditions the incubation period is probably in the neighborhood of two weeks.

When first laid the eggs are white but they soon change to brown as development begins.

The activity of the beetles as well as the rate of egg-laying is closely correlated with temperature, being directly proportional to the rise and fall in temperature but of those eggs that are laid at high temperatures, i. e. 85°F. or higher only a small percentage hatch. In other words, the lower temperatures are more favorable towards initiating development in the eggs than are the higher temperatures. Once development has started, however, the eggs proceed with their development more rapidly at higher than at lower temperatures.

The newly hatched larvae begin their feeding on the crowns of the alfalfa plant but they soon burrow down to the root pruning off the side roots and then attacking the tap root. They burrow into the root or gouge out large holes or burrows on the outside and eventually cut off the root entirely. The larvae follow the roots of the plants far into the soil. Whereas the majority of the larvae occur in the upper 8 or 10 inches of soil many larvae were found as deep as 15 and 20 inches below the surface and a few specimens were taken at a depth of 26 inches. In several places plants were dug up with their root systems cut off 28 inches below the surface, indicating that the larvae may go at least as deep as this, if not deeper. In severely infested fields it was not uncommon to find as many as 200 grubs per cubic foot of soil and when diggings were made to a depth of two feet, more than 250 larvae were found per square foot of surface area. Where such heavy infestations occur the grubs destroy practically the entire roots.

The larvae apparently pass through seven instars and when fully mature they measure about 12 mm. or half an inch, in length. The grubs pass the winter in cells in the soil. Overwintered larvae were taken at depths ranging from three to 26 inches with an average mean depth of 11.042 inches, based on 407 larvae.

In addition to alfalfa the larvae have been found feeding on the roots of red clover, alsike clover, white and yellow sweet clover, narrow and broad leaved dock, wild carrot, wild strawberry, grapes, quack grass, timothy and a few other plants.

Having passed the first winter as larvae in the soil, the grubs transform to pupae late in the spring or early summer. The first pupa was taken from the field on June 7 and on July 24 there were still a few pupae found which had not yet transformed to adults. The average pupal period lasted from 21 to 25 days.

The newly transformed adults remain inactive in the soil all during the remainder of the summer, fall and winter and emerge the following spring, thus completing the two-year cycle.

Alternate cycles seem to have become fully established for indications are that the emergence next spring will be just as great as it was this past spring.

Of considerable interest is the fact that just recently Mr. Buchanon of the National Museum in Washington has come across a specimen of *Brachyrhinus ligustici* bearing the label: "Oswego, New York, May 16, 1896, Wickham." This would indicate that the alfalfa snout beetle has been in this country nearly 40 years or possibly longer. However, the area immediately around Oswego, New York, is not particularly well adapted to alfalfa growing and farmers have only begun raising alfalfa there within the last 10 or 15 years. Possibly the weevils were barely able to maintain themselves on host plants other than alfalfa until alfalfa came to be planted when they began to build up this tremendous population. Since the belt of extensive alfalfa growing in New York is situated only about 20 miles to the south of the infested area, it is sincerely hoped that some effective means of controlling this pest may be found before it has a chance to become further spread.

We have had very little opportunity thus far to devise control methods. No feasible methods have yet been suggested towards reaching the larvae and pupae which occur in the soil as deep as 24 to 28 inches below the surface. The principal mode of attack will probably have to be directed towards the adults at the time when they emerge from the ground. Spraying the fields with arsenicals killed a large number of the adults and at the time when they began their migrations trench barriers caught large quantities of the beetles. Naphthalene barriers were found to be very effective in checking migrations.

SUMMARY.—The alfalfa snout beetle, *Brachyrhinus ligustici* (L.) is a new insect pest of leguminous forage crops in this country, particularly of alfalfa. Because of its extensive damage in Europe and parts of Asia, its presence here is looked upon with great concern. The insect has a two-year life cycle in its native home and it apparently will deviate but little from this in New York. Adults appear in the early spring, feed on the foliage of various plants and migrate in search of larval host plants. Egg-laying begins late in May and continues through most of July. The beetles are parthenogenetic and deposit an average of over 300 eggs each. Larvae hatch approximately two weeks after the eggs are laid. Their feeding injury to the root systems of alfalfa and other hosts often kills the plants outright. Mature larvae overwinter in the soil and pupate the following June and July. The newly formed adults remain inactive in the old pupal cells until the following spring, emerging two years after the eggs are laid.

Heavily infested areas can be located during July and August by the yellowing and dying of the foliage of the injured alfalfa plants. These plants can easily be pulled up because their root systems are badly injured. In September, October, and November, dead areas in fields can be spotted and grubs easily found near the surface, feeding on the remaining roots of the injured and dying plants. During April and May these dead areas stand out in contrast to the growing foliage of the living plants.

Replying to queries, the authors stated that no males were observed, that parthenogenesis did occur among related American species, that sweet clover was attacked, alfalfa being preferred, that injury to soy beans was not observed, that peas were not attacked, that the beetles winter in the soil so far as observed.

***Sphaerites glabratus* from British Columbia. (Coleop.: Sphaeritidae).** In working over the *Silphidae* in the collection of the Department of Entomology of the University of Nebraska, the writer located a specimen which, due to the rareness of the species and its limited geographic distribution, it was thought advisable to place on record. *Sphaerites glabratus* was first described under the name *Hister glabratus* by Fabricius in 1792 from North Europe. It has since been found in Alaska and California. A synonym is *S. politus* Mann. The specimen here recorded was sent to the Department of Entomology by the late Henry F. Wickham. It was taken at Masset Inlet, Queen Charlotte Islands, British Columbia. There is no date or name of collector on the label. *Sphaerites glabratus* is the only species of the genus and the genus to which it belongs is the only one in the family.

F. G. MESERVE, *University of Nebraska, Lincoln, Nebr.*

THE EFFECT OF FOOD PLANTS ON THE DEVELOPMENT OF THE PALE WESTERN CUTWORM (*AGROTIS ORTHOGONIA* MORR.)

By H. L. SEAMANS and ELLIS MCMILLAN, *Dominion Entomological Laboratory, Lethbridge*

Since 1911, the pale western cutworm (*Agrotis orthogonia* Morr.) has been an increasing menace to crops in the treeless prairie areas of Canada. Outbreaks of this insect have also occurred in the states of North Dakota, Montana, Wyoming, Colorado and Oklahoma indicating that it occurs over the greater part of the Great Plains area.

In its native habitat the pale western cutworm feeds on the stems of grasses and where these grasses have been destroyed by agriculture it has turned its attention to a wide variety of plants. In Canada practically every field and garden crop is attacked as well as many of the common weeds. There seems to be little food preference except that stink weed (*Thlapse arvense* L.) and veined dock (*Rumex venosus* Pursh.) are only eaten sparingly even when no other food plants are available. The larvae have also been found feeding on decaying straw or other vegetable matter after all green vegetation was destroyed.

DEVELOPMENT OF THE LARVAE IN THE FIELD AND LABORATORY.—In Canada the overwintering eggs usually start to hatch about April 25 and hatching continues up until about May 10. Hatching and larval development are very uneven and larvae of several instars may be found in the field at one time. In spite of this, the prepupal stage is reached between June 10 and June 25 and some of those larvae hatching first may be the last to become full grown. The active period of individual larvae in the field from hatching to prepupal inactivity may vary from 31 to 61 days.

Larvae reared in the laboratory have seldom developed at a rate equal to those in the field. In no case, except when fed on wheat, have larvae been reared to the prepupal stage in less than 49 days and the average period of activity of reared larvae is 69 days. Some have continued feeding for 179 days before reaching the prepupal stage. The longer period of development has always been associated with a higher death rate, the larvae in the laboratory apparently dying of a disease which has not been found in the field.

Because of the apparently omnivorous nature of the pale western cutworm, laboratory rearing has been carried on using either dandelion (*Taraxacum officionale* Weber) or wandering Jew (*Tradescantia* sp.) as food. These plants were chosen because of their availability at all times of the year and because the larvae seemed to feed on them without any hesitation. It was not until field observations indicated that larvae feeding on oats and barley developed more slowly than those feeding on wheat that the question of the importance of particular food plants arose.

REARING METHODS.—Experiments with food plants have been conducted by using larvae collected in the field as well as those hatched from eggs. In all cases each larva has been isolated in a one ounce seamless tin

box as soon as it was collected, following the method described by King and Atkinson.[1] This method has been found to greatly reduce mortality from a suspected "laboratory disease" which invariably destroyed a bulk collection made in the field.

In rearing, the isolated larvae were given fresh food every other day. All remnants of food were removed from the tins and these were thoroughly cleaned before the new food was introduced. The larvae were handled as little as possible but when it was necessary to pick them up, the forceps used were dipped in 90 per cent alcohol before other larvae were touched. All cans containing larvae were kept under identical conditions of moisture and temperature in the laboratory. All moults and changes in activity were noted and the sex of pupae and adults was recorded.

In the experiments conducted to date, with one exception, one hundred larvae have been started on each plant food. When larvae have been collected in the field, parasitism may destroy many of them before they pupate or emerge as adult moths. This condition is aggravated in some cases where it is necessary to use food plants taken from the field which may carry parasite eggs or larvae.

In order to minimize the effect of natural parasitism as a factor in influencing the results, collections were made from a single field or mixed collections were so grouped that an equal number of larvae from several fields were included in each series. As the collected larvae varied in development from the third to the sixth instar these different stages were likewise distributed throughout the series. With such larvae, the constant use of one plant food in the rearing work influenced their development for a comparatively short period. Thus the results were not as marked as they were with larvae hatched from eggs. The point of the study was to determine what rate of development, sex survival and mortality was to be expected in a field when the original crop has been destroyed and other plants only are available for food.

The prepupal larvae taken when making the collections were used as a check on field conditions. This material required no more feeding and was kept under the same conditions as the larvae being reared. All were collected from wheat fields in which a little grass was growing.

The following plants were used in this work during 1933 and 1934: spring wheat, winter wheat, oats, barley, winter rye, dandelion, wandering Jew, alfalfa, sweet clover (white), native grass (*Agropyron smithii* Rydb.), Russian thistle (*Salsola pestifer* A. Nels), Canadian thistle (*Cirsium arvense* L.), sugar beets, pig weed (*Chenopodium album* L.), stink weed (*Thlapse arvense* L.) and wet stubble. One small series of 38 larvae were starved for 17 days and then fed on wheat until full grown. Only spring wheat, oats, barley, dandelion, alfalfa, sweet clover, grass and Russian thistle, however, have been used both years.

DIRECT EFFECT OF FOOD PLANTS ON THE LARVAE.—Preliminary experiments have indicated that food has a direct effect on the larvae of the pale western cutworm. This effect is shown in three ways: (1) by

[1]Journal of Economic Entomology, Vol. 20, pp. 822–830.

the numbers of unparasitized larvae and pupae which fail to mature, (2) by the length of the period of larval development, and (3) by the sex ratio of pupae and moths. The evidence indicates that some readily eaten plants may be factors in natural control and materially assist in reducing an outbreak.

With four of the food plants used, namely, wandering Jew, wet stubble, pig weed and stink weed, over 50 per cent of the larvae or pupae died of no known cause other than what has been called "laboratory disease". Of the larvae fed on wandering Jew, 85 per cent died and all the pupae were deformed. With wet stubble the mortality was 84 per cent, pig weed 59 per cent and stink weed 51 per cent. A second group of plants was associated with a mortality of over 30 per cent of the larvae; those fed on Russian thistle showing a mortality of 34.5 per cent, sugar beets, 32 per cent, the starvation series 31.6 per cent, and Canada thistle 30 per cent. Feeding dandelion, alfalfa, sweet clover, winter wheat and barley produced a larval mortality of from 23 per cent to 21 per cent in the order named while the mortality of larvae which were fed on spring wheat, grass, oats and winter rye in no case exceeded 19 per cent and with some plants was as low as 5.5 per cent.

While it is realized that the starvation series was only carried with a small number of larvae (38) in this preliminary work, it is interesting to note the implication that if a crop has been destroyed by pale western cutworm, reseeding to wheat after a short period of starvation might be of greater benefit to the larvae than leaving the field unseeded and forcing them to feed on pig weed, Russian thistle or rotting stubble.

Larvae collected in the field as these were, have only a short period of activity left which, judging from field development, average from 15 to 20 days and the average length of this period will vary with the numbers of larvae of each instar which matures. Since unhealthy larvae may linger for a long time and then die, only those which succeed in reaching the prepupal stage were considered in determining the delays in development occasioned by food plants.

The most rapid development occurred among larvae fed on grains, grass and alfalfa. The greatest lag in development occurred when wandering Jew, pig weed, Canada thistle and Russian thistle were used for food. The other broad leaved plants and decaying stubble group together between these two extremes with stink weed causing the slowest development and dandelion the most rapid.

Up to the present, no work has been done so far as we know indicating the effect of larval food of noctuids on the determination of the sex of the moths. There is some evidence arising from these experiments with food plants that indicates either a sex determination or a differential sex survival in pale western cutworm resulting from this cause. The larvae of the check series collected in the prepupal stage produced virtually equal numbers of male and female pupae. The larvae fed on spring wheat, oats, barley, rye, wandering Jew, sugar beets and the starvation series definitely produced more female than male pupae while the reverse was true when alfalfa, sweet clover, grass, winter wheat, Russian thistle, Canada thistle, pig weed and stink weed were

fed. When wet stubble was used as food the pupae, though few, were equally divided between the sexes.

A preponderance of pupae of one sex does not always mean there will be a preponderance of moths of that sex and the expected ratios were reversed in the series fed on wandering Jew, alfalfa, grass, Russian thistle, pig weed, Canada thistle, stink weed and the check. In some cases the reversal is not very great but a study of the rearing records shows that practically 60 per cent of the pupae which died of disease were males. This might indicate that the food plant did not provide sufficient vitality for the males to emerge or that the female larvae lacked the necessary vitality even to pupate.

An experiment was conducted with newly hatched larvae which were isolated in a series of 100 tins and fed on wheat, oats, rye, barley and wandering Jew. The larvae fed very readily on wheat or rye but frequently hesitated a day before feeding on oats, barley or wandering Jew. The death rate was greatest among larvae fed on wandering Jew, the rate decreasing in the order named when fed on barley, rye, oats and wheat. Cage and field experiments to determine the value of barley for reseeding infested fields indicated that an infestation of pale western cutworms sufficient to destroy 85 per cent of a reseeded crop of wheat only destroyed 52 per cent or less of a crop of barley seeded at the same time.

INDIRECT EFFECT OF FOOD PLANTS ON THE LARVAE.—Food plants may influence the larvae of pale western cutworm indirectly by their effect on natural parasites. There are two very common parasitic tachinids of the pale western cutworm which deposit eggs or larvae on vegetation. These are *Bonnetia comta* Fall. and *Gonia* spp., and both appear to prefer grasses or grains for oviposition. The percentage of cutworm larvae parasitized by these species increases as the feeding season advances particularly if the cutworms are feeding on any portion of the plant above ground and accessible for parasite oviposition.

The check collection containing larvae which had completed feeding for the season had a natural parasitism by these species of 49.5 per cent. A collection of larvae made at the same time as the rest of the material for 1934 work and fed on parasite free wheat until mature, was only parasitized to the extent of 37.7 per cent. Using this point as a probable average it is reasonably safe to assume that the average parasitism of the entire series at the time of collection was from 35 to 40 per cent. Rye and wandering Jew were not used as food plants in 1934 and no information on parasitism for these two plants is available.

A marked increase in parasitism occurred among the larvae fed on winter wheat (58%), oats (54%), grass (50%), Canada thistle (50%), check (49.5%), spring wheat (48%) and sugar beets (47%). The parasitism of larvae feeding on dandelion (40%), Russian thistle (40%), alfalfa (39%), sweet clover (38%), barley (36%) and stink weed (34%) was within or close to the average limits while that of pig weed (31%), the starvation series (13.1%) and wet stubble (7%) indicated that many parasitized larvae and their parasites died before pupation.

These studies suggest that the relationship between an omnivorous insect and the plants upon which it is known to feed may be a very profitable and practical line of investigation. The results of the preliminary work reported here indicate that in so far as the pale western cutworm is concerned, the survival of larvae, variations in development, the sex of adults and the relationship between parasites and host vary with the food plant. Future investigation along this line must be conducted to verify the results already obtained and the application of these to a practical cropping system of control of the insect.

FORECASTING OUTBREAKS OF THE PALE WESTERN CUTWORM (*AGROTIS ORTHOGONIA* MORR.)

By H. L. SEAMANS, *Entomological Laboratory, Lethbridge, Alberta*

The control of the pale western cutworm (*Agrotis orthogonia* Morr.) in Canada is effected by means of definite cultural practices. These are designed to prevent the moths from ovipositing in certain fields during August and early September, thereby insuring the farmer of cutworm free land during the following crop year. In order that such a control might have the greatest practical value it was necessary, in view of the habits of the insect, to devise a method of forecasting outbreaks well in advance of the time at which control practices had to be undertaken. This was attempted first during the winter of 1922–23 when a tentative forecast for 1923 was made.[1] This was so successful that in July 1923 a forecast of cutworm outbreaks for 1924 was published. Since that time, the expected abundance of the pale western cutworm for the following year has been forecasted and published each July. At first this was restricted in its application to the province of Alberta but as outbreaks of the insect began to appear in the province of Saskatchewan the forecast was extended in 1929 to cover the infestations in both Provinces.

BASIS FOR THE FORECAST.—The forecast is based on the fact that rainfall brings the larvae of the pale western cutworm to the surface of the soil where they move about exposed to parasites and predators and feed on the upper portions of their food plants which carry parasite eggs and larvae. As the larvae usually feed throughout May and most of June, the forecast was originally based on the precipitation of these two months. When it was found necessary to include Saskatchewan in the forecast the variations in the period of larval development had to be accommodated and the precipitation for "the period of larval development" was substituted for the former calendar period.

Rearing records have proven that the number of larvae which are destroyed by parasites is to all practical purposes directly proportional to the number of days they are forced to move about on the surface of the soil or feed on the upper portions of the plants. Not only is the infestation by any one parasite found to be greater, but the number of

[1]Seamans, H. L. "Forecasting Outbreaks of the Pale Western Cutworm in Alberta" Can. Ent. Vol. 55. 3pp. 51–53.

species is greatly increased in a wet season. For this reason, attempts to base a forecast on total precipitation for the period were not as successful as when the forecast was based upon the number of days upon which precipitation took place.

Field observations showed that a rainfall of 0.25 inches on one day was sufficient to bring the cutworms to the surface of most soils. Any day with a precipitation of 0.25 inches or more, was therefore considered a "wet day." It was also found that soil too wet to be easily worked with a disc harrow kept the cutworms on the surface. Such days, therefore, for cutworm forecast purposes should be considered as "wet days." A rainfall lasting for two to three days often resulted in four or five such effective "wet days" in respect to the behaviour of the cutworms. Hence the forecast in particular localities is more accurate if the "wet days" are recorded by individual days made up of the "wet days" due to definite rainfall and those upon which culture with a disc harrow is not possible. The publication of a widespread forecast, however, must of necessity depend on the calculation of "wet days" from the official daily precipitation records by localities throughout the entire area and these in turn weighted somewhat by a general knowledge of the soil conditions. If any locality is found to have had less than 10 "wet days" during the period of larval activity an increase in cutworm abundance can be expected the next season. If there are from 10 to 15 "wet days" there will be little change in the population but if more than 15 such days occur the pale western cutworm is expected to be economically important for the next year.

Cook[2] developed a method of forecasting outbreaks in Montana in which he used the total precipitation for May, June and July. This method has not proven as satisfactory in Canada as the "wet day" method. Including July rainfall results in the forecast not being available for publication sufficiently early in the year for that part of the cultural program which falls in July to be put into effect. Total rainfall is misleading in those localities where a sudden cloudburst of two or three inches of rain in a few hours does not penetrate the soil sufficiently to cause more than one "wet day." In some cases, attempting to count "wet days" by the number of 0.25 inch units which occur in the total rainfall may be seriously inaccurate from the forecast viewpoint. Since the term "wet day" refers to the moisture condition of the soil and not necessarily to the amount of rainfall, the unit of 0.25 inches is to be considered simply as a compromise average which on practically all soils will bring the cutworms to the surface.

RESULTS OF THE FORECASTING.—Until 1925 the forecast only covered those areas of Alberta which had previously experienced outbreaks of the pale western cutworm. In 1925 a serious and unexpected outbreak appeared 150 miles north of any previously known infested area. The insect had never been reported from the locality though subsequent observations indicated that it had apparently been present in some numbers since 1924. After the event, however, a glance at the weather records for

[2]Cook, W. C. "Some Weather Relations of the Pale Western Cutworm", Ecology Vol. 7 (I), pp. 37–47.

1924 was sufficient to indicate that an outbreak for 1925 could have been forecasted and the failure to do this lay not in the method of forecasting but in the lack of realization that the area was in the cutworm infested zone. At the same time equally unexpected local outbreaks appeared at Regina and Indian Head, Saskatchewan, some 300 miles east of the former record of outbreaks.

The forecast published in 1925 predicted a reduction of the outbreak in Alberta and a probable continuance of the trouble in Saskatchewan in 1926. The verification of this forecast by the subsequent infestation in 1926 freely justified the attempt of using it on a much wider scale than previously. During the next four years the detailed forecasts were largely confined to Alberta, only occasional references being made regarding the situation in Saskatchewan for the guidance of the officers in charge of the entomological work for that Province. Alberta was enjoying a cutworm free period with the annual prediction suggesting that it would remain so being regularly justified by subsequent developments. Saskatchewan, on the other hand, was experiencing a series of local outbreaks of more or less intensity indicating the general presence of the insect throughout the Province.

The first general forecast involving both provinces was made in 1929 and predicted several local outbreaks of a severe nature with a fairly widespread but less severe general increase in cutworms in 1930. By July of this year it was evident that the 1929 forecast was correct to a surprising degree and that an outbreak of major proportions could be expected in 1931. When the forecast was completed and mapped in July 1930 it showed an infestation of varying intensity extending for 550 miles from Wolseley, Saskatchewan, west to Macleod, Alberta, and northward for 300 miles from the International Boundary. There were some localities within the general outbreak zone in which the insects were not expected to be present and so the total area of possible infestation in 1931 was estimated at 100,000 square miles. The outbreak of 1931 materialized essentially as forecasted even to the intensity in different areas.

A forecast for 1932 was mapped and published the first week of July, predicting a greater area of outbreak extending from Summerberry in eastern Saskatchewan to Cowley, Alberta, in the Rocky mountains. The entire area of predicted infestation comprised over 150,000 square miles and subsequent events proved that the infestation over this area corresponded remarkably with the anticipated conditions.

As the season of 1932 advanced, some districts, particularly in the east and north, had an excellent distribution of rainfall and the forecast published in July 1932 predicted a marked reduction of the outbreak in 1933. This not only meant a reduction in the extent of the general outbreak but also a reduction of the intensity in local areas. A few districts remained fairly dry throughout the season and in these an increased infestation was forecasted. The actual outbreak in 1933 again fully justified the increasing confidence in the forecast.

The season of 1933 was one of extremely varied weather conditions. Some areas had an abundance of rainfall while adjacent localities suffered

from severe drought. These conditions were reflected in the forecast for 1934 which predicted a further reduction of the outbreak in Saskatchewan but showed an increase in the area of severe infestation in southern Alberta. In both provinces, local areas of very severe infestation were predicted and mapped. The presence of pale western cutworms in 1934 showed that the forecast was remarkably accurate. No areas of severe infestation were missed in the prediction and the general infestation corresponded very closely with the map.

The forecasts of pale western cutworm outbreaks based on the "wet days" occurring during the period of larval activity have been published and verified for eleven years. These forecasts have been extremely accurate in predicting the relative abundance of the insect by localities over a very extensive area. At no time has a locality suffered from a severe infestation when the forecast predicted that cutworms would not be present. Farmers generally have been thoroughly convinced of the accuracy of the annual forecast and make free use of it in planning their season's operations.

A SURVEY OF CUTWORM DAMAGE IN A SPECIMEN LOCALITY IN SASKATCHEWAN

By ELLIS MCMILLAN, *Assistant Entomologist, Dominion Entomological Laboratory, Lethbridge, Alberta*

Cutworms have caused damage to cereal crops in Western Canada many times since the beginning of prairie agriculture, but the most severe and most widespread losses ever recorded were sustained during the years 1927 to 1933, due to the ravages of the pale western cutworm (*Agrotis orthogonia* Morr.). Although several workers have estimated the percentage of loss caused by cutworms, there has been to date no definite information based upon a careful appraisal in any given area to serve as an authoritative guide which could be used in making such estimates.

In order to obtain such data, a survey was carried out in 1931 as a cooperative project by the Agricultural Economics Branch and the Entomological Branch, both of the Department of Agriculture of the Dominion of Canada. The study was made in two areas, one in the vicinity of Elstow, 33 miles east of Saskatoon, Saskatchewan, and the other in the Aberdeen locality, 30 miles northeast of Saskatoon comprising a total of 14 townships. These areas were selected because they had the most extensive and severe outbreak of pale western cutworm in the northern part of the province. Other areas in Saskatchewan were not suited to such a study as the cutworm losses would have been too greatly confused by the wind damage and the severe drought conditions. In the two areas selected, wind damage, as estimated by the farmers, caused only 5½ per cent of loss at Elstow (3416 acres) and about 1.7 per cent of loss at Aberdeen (1130 acres). Since this acreage was not included in any of the calculations of values and percentages, it is felt that this has not influenced the data to an appreciable extent.

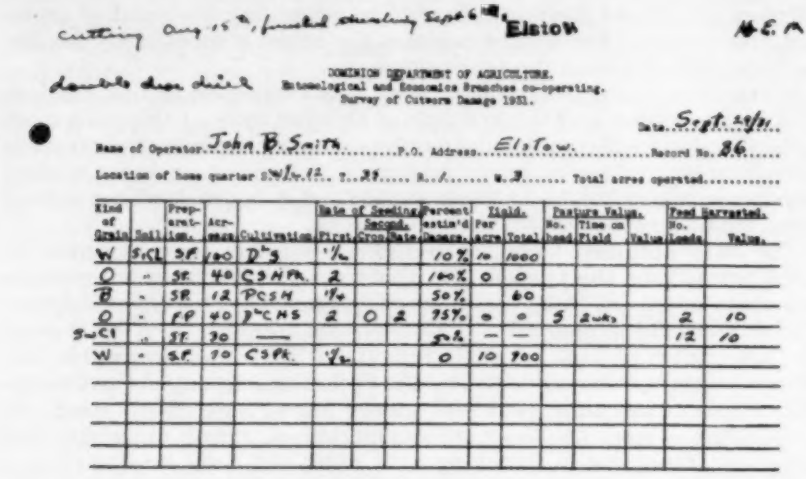
The general plan adopted in securing the data was outlined in cooperation with Dr. J. F. Booth, Commissioner, Agricultural Economics Branch of the Dominion Department of Agriculture. Messrs. E. Grest and F. Hitchcock of the Agricultural Economics Branch assisted in gathering the data in the field along with officers of the Entomological Branch including, in addition to the writer, Messrs. G. F. Manson, L. C. Paul and C. W. Farstad. Dr. William Allen, Professor of Farm Management, University of Saskatchewan, supplied the information on prices of grains and the methods used in estimating the value of green feed and pasture. The author assumes the entire responsibility for the analysis of the data and the conclusions.

METHOD OF STUDY.—The field work was carried on during the last week in September and the first half of October since at this time most of the threshing was completed. In order to make certain that the records were accurate and consistent an economist and an entomologist worked together in taking the field records at the start, later, each officer worked alone, six officers taking part in the field work.

The data obtained from the individual farmers were recorded on forms printed for the purpose. On this form the following information was recorded:— (1) *Date;* (2) *Name of operator;* (3) *Post Office Address;* (4) *Location of home quarters;* (5) *Total acreage operated;* (6) *Kind of grain* (7) *Soil*—notes of local interest were taken from the farmer, but the soil type designations indicated by the Soils Department of the University of Saskatchewan in their soil survey maps, were chiefly used; (8) *Preparation of land for the crop*—summerfallow, spring ploughing, fall ploughing, stubbling-in, breaking with date; (9) *Total acreage in each field;* (10) *Cultivation*—each operation on each field in order of their occurrence was recorded, such as ploughing, harrowing, double discing, rod-weeding, etc. (11) *Rate of seeding*— of the original crop. If destroyed, then the rate of the second seeding was recorded and also the kind of grain used for reseeding; (12) *Percentage estimated damage*—the farmer's estimate in per cent of acreage; (13) *Yield*—either bushels per acre, or total yield, or both; (14) *Pasture value*—three items are listed under pasture value but the most important was the final estimate of value. Items, number of head of stock and time on field, were designated only as an aid to obtaining the value in case the farmer could not give an estimate of the value of the pasture which he obtained from the field. This pasture value was most frequently obtained where a second crop was sown and failed to reach maturity, but in some cases the farmers considered the original seeding not worth cutting and simply turned the stock on it to pasture; (15) *Feed harvested*—intended for use where either the first or second sown crop was harvested as feed rather than as actual threshed grain. The value was the important item but as with pasture values, the number of loads was obtained in order to calculate an approximate value.

Below, there is reproduced a specimen copy of the form outlined above as completed in the survey of the farm of John B. Smith at Elstow, September 29, 1931.

In calculating total values it was often necessary to estimate a price for feed and for pasture since many farmers were not able to supply this information. After a consideration of the values of feed estimated by farmers, it was decided that a price of not more than $3.00 per load be used. If the value given by the farmer was less than that, the lower price was used. With regard to pasture values, a price of $1.00 per head per month was used unless the farmer gave a value less than $1.00.



cutting Aug 15th, finished threshing Sept 6th, Elstow

double disc drill

DOMINION DEPARTMENT OF AGRICULTURE.
Entomological and Economics Branches co-operating.
Survey of Cutworm Damage 1931.

Date Sept. 29/31

Name of Operator John B. Smith P.O. Address Elstow Record No. 86

Location of home quarter SW¼ 12 T. 28 R. 1 W. 3 Total acres operated

Kind of Grain	Soil	Preparation	Acreage	Cultivation	Date of Seeding First	Second	From	Date	Percent estim'd Damage	Yield. Per Acre	Total	Pasture Value. No. head	Time on Field	Value	Feed Harvested. No. Loads	Value.
W	SiCl	SF	100	D²3	1/4				10%	10	1000					
O	"	SF	40	C3HPk	2				100%	0	0					
B	"	SF	12	PC3H	1/4				50%		60					
O	"	FP	40	P²C H S	2	0	2		75%	0	0	5	2wks		2	10
SwCl	"	St	20	——					50%	—	—				12	10
W	"	SF	70	C3Pk	1/4				0	10	700					

FIG. 60.—Form used in cutworm survey.

W — wheat
O — oats
B — barley
R — spring rye
FR — fall rye
F — flax
SwCl — sweet clover
A — alfalfa

SF — summerfallow
St — stubble
SpP — spring ploughing
FP — fall ploughing
Br — breaking

SiCL — silty clay loam
SiC — silty clay
LC — light clay
CL — clay loam
HvL — heavy loam
C — clay
SdL — sandy loam
Alk — alkaline
HvSiC — heavy silty clay

D—single disced; D²—double disced; P—ploughed; H—harrowed; Rw—rod-weeded; Pk—packed; Fl—floated; C—cultivated; C²— cultivated twice; S—seeded; Past—pastured; R—harvested; R²—combined; R³—swathed.

In considering the price of grain, Fort William, Ont., prices of October 15th were used. From these prices was subtracted the cost of threshing and carrying charges to Fort William (freight and handling charges). The following prices were then used: No. 1 hard wheat $0.60, oats $0.30, flax $0.88, rye $0.36, barley $0.32.

After deducting the charges, the following prices were used in calculating values: wheat $0.37, oats $0.20, flax $0.50, rye $0.25, barley $0.20.

In the preliminary working up of the data, the records were divided according to the kind of grain and the preparation. The data was tabulated according to the following categories: Fields with no damage;

fields damaged 1–10 per cent, fields damaged 11–30 per cent; fields damaged 31–60 per cent and fields damaged 61–100 per cent. It was felt that these divisions were more satisfactory in calculating damage values, etc., than other categories which had been suggested.

RESULTS OF THE SURVEY.—It would be quite uninteresting at the present time to give at length the detailed results of this survey by land preparations or crops. The mass of data accumulated has furnished many leads for future investigations toward more sane cropping practices wherever this species of cutworm is present. In the area under observation in this survey, the gross loss to the farming public on 23,909 acres was $31,859.29. Moreover, this loss did not include the farm operating costs for this acreage. Estimating a conservative average operating cost of $5.00 per acre this would increase the loss by $119,545.00, making a grand total loss of $151,404.29 or $6.33 per acre. When it is remembered that about 3,000,000 acres were infested with the pale western cutworm during the general outbreak of 1929–1932, the importance of cutworm control is easily understood. Further, it should be realized that the data presented here was obtained in a year when wheat prices were almost at the lowest level over a long period of years. The combination of this factor and that of low yields reduced the loss by a considerable margin.

PSYLLID YELLOWS OF TOMATOES AND CONTROL OF THE PSYLLID, *PARATRIOZA COCKERELLI* SULC., BY THE USE OF SULPHUR

By GEO. M. LIST, *Colorado Experiment Station, Fort Collins*

The tomato is one of the preferred hosts of the Psyllid, *Paratrioza cockerelli* Sulc. The feeding of the nymphs causes a condition similar to psyllid yellows of potatoes, described by Richards (5) 1927. The exact cause of this definite plant reaction is not known, but the best evidence supports the theory that a toxic substance is injected during the process of feeding. This theory is strongly supported by the fact that when the nymphs are removed the host will recover.

Probably the best early diagnostic symptoms of psyllid yellows of tomatoes is the upward rolling of the basal portion of the older leaves and often twisting of their petioles. There is usually a slight purpling of the veins and margins of the younger leaves. Their basic color usually becomes a light or yellowish green. There is a slight puckering of terminal leaves and a tendency for them to stand more upright. They never attain a normal size, the leaflets being narrow and the petioles slender. The stem diameter of the growing tips becomes greatly reduced, giving the entire top of the plant a "feathery" appearance. In case of an early attack when the plant is small, the internodes are shortened with the entire plant taking on a very stunted appearance. Such a plant may remain in an inactive state of growth for weeks. When the attack becomes severe after the vegetative growth is well advanced the internodes

may be lengthened and greatly reduced in diameter and the leaves much narrowed.

The setting of fruit is not seriously interferred with only that the stunting of growth very materially limits the number of fruit clusters.

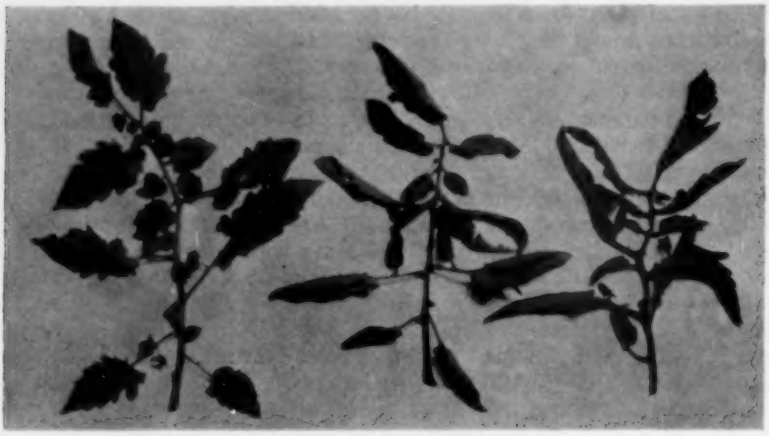


FIG. 61.—The leaf on the left is a normal tomato leaf. The one in the center shows the upward rolling of the leaflets, an early symptom of psyllid yellows. The leaf on the right represents a well developed case of psyllid yellows. Note the curled leaflets, twisted petioles and the angular leaf stem. All are older leaves from fruiting plants.

FIG. 62.—The stem on the left is from a normal tomato plant. The one in the center is from a plant showing a well developed case of psyllid yellows while the one on the right represents the symptoms of a case still farther advanced. Note the small leaves, reduced diameter of the stems and stunted growth with small fruits and blossoms almost to the growing tip.

The size and quality of the fruits are seriously affected. The effect upon the size is well brought out in the tables showing yields of the experimental plots. The effect upon the quality is very marked. This is evident

in fruits from plants that are so lightly infested that they do not show the leaf and growth symptoms and is very evident in the fruits of plants in which the yellows has developed to the point of showing growth symptoms. The central mass and the partition walls fail to color normally upon ripening, are tough and even rubbery in extreme cases. The juicy pulp about the seeds is much reduced, often to the extent of leaving cavities. The outer walls do not color normally and as a result the fruits

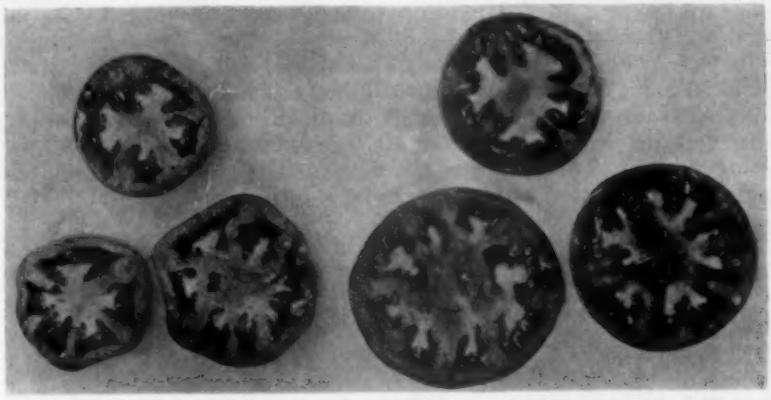


FIG. 63.—The three fruits on the left were from untreated plants heavily infested with psyllid nymphs. Those on the right were from plants in the same field that had received three applications of sulphur dust for psyllid control. The largest fruit was 3½ inches in diameter. Note the angular shape of the psyllid-injured fruits and their thinner cell walls. The central masses are firm and pithy. The juicy pulp about the placentae is reduced and some cavities exist.

never attain their true natural color. The natural red and purple of the standard varieties take on a yellowish cast that is very undesirable. The housewife soon learns that this is an indication of an insipid taste, and general lack of quality.

An interesting part of the problem is that when the psyllids are removed the plant shows a marked tendency to recover. The rapidity and extent of recovery depends upon the degree and length of standing of injury. In 1918 the writer (3) showed that lime sulphur, one gallon of the standard commercial liquid to 40–45 and 50 gallons of water, gave a marked control of the tomato psyllid. In 1934 List & Daniels (2) made a preliminary report of the effectiveness of this combination in controlling the psyllid on potatoes. This was reported more fully by Daniels (1) a little later that same year. The material has had two years of very severe tests in commercial potato production in Colorado, its use in many cases making the difference between no crop and a good commercial yield.

The use of lime sulphur on tomatoes has often been attended with a burning or a temporary shock to the plants, that is objectionable. The more rapidly growing plants show the most injury. Studies were made

this season to learn more of this effect, how lime sulphur controls, and to test possible substitutes. The following are some of the more outstanding results.

REPELLENT EFFECT UPON PSYLLID ADULTS.—List (4) 1934 called attention to a very definite repellent effect of lime sulphur on adult psyllids in the greenhouse. This was tested in the field by placing a muslin cage over individual plants and then shaking the plant to cause the adults to move to the sides of the cage where they could be collected and counted. Ten plants were sampled in each plot. Treatments and checks were paired and the data analized by Student's Method. The following materials were used: Commercial liquid lime sulphur 33 degrees Baume 1 part to 50 parts of water; dry lime sulphur 1 pound to 10 gallons water; sulphur and lime sulphur dust made up of 75 per cent dusting sulphur, 15 per cent dry lime sulphur and 10 per cent bentonite; and 200 mesh dusting sulphur. Table 1 gives the results. The counts were made one week after application of the materials.

TABLE 1. SHOWING THE REPELLENT EFFECT OF CERTAIN MATERIALS ON TOMATO PSYLLID ADULTS

Material	Average reduction	Standard error	Average number nymphs on checks
Liquid lime sulphur 1–50	8.1	±2.66	8.9
Dry lime sulphur 1–10	13.3	±2.6	15.1
Sulphur and lime sulphur dust	10.2	± .77	11.7
Sulphur dust	11.7	±2.08	13.1

It will be seen that all materials had a definite repellent effect, and there is no difference between treatments. Observations on other plots varified this.

LETHAL EFFECT UPON PSYLLID NYMPHS.—The effectiveness of certain materials in killing nymphs is shown in Table 2. The treatments were applied in a rather heavily infested field. Then 15 days after application two ounce samples of leaves, so selected as to represent a fair sample of the entire plant, were taken from each of 8 plants in each plot and all nymphs counted. The samples from the pyrethrum and derris treated blocks and their check were taken 5 days after treatment.

TABLE 2. SHOWING THE EFFECT OF CERTAIN SPRAYS AND DUSTS ON PSYLLID NYMPH POPULATIONS ON TWO OUNCE SAMPLES OF TOMATO LEAVES

Material	Average populations
Sulphur and dry lime sulphur dust	.6
Sulphur dust, 200 mesh	.3
Sulphur dust, 300 mesh	1.
Liquid lime sulphur 1–50	1.
Check	193.
Pyrethrum powder .18 per cent pyrethrins	280.3
Derris powder, .5 per cent rotenone	229.
Check	367.5

All of the sulphurs showed a very marked kill. There was no difference in their effectiveness. The pyrethrum and derris dusts were not effective in the strengths used.

A two ounce sample of leaves probably represented from one-sixth to one-tenth of the leaf surface of a plant. The total population on a plant similar to the ones treated is indicated by three counts of entire plants

made in a nearby field. These carried 719, 1925 and 3116 nymphs respectively. They also averaged 1013 eggs and 17.3 adults.

EFFECT OF PSYLLID CONTROL ON YIELD.—Practical control tests were made in a number of fields. Due to the fact that these were commercial plantings not under our immediate control, and were picked 2 and 3 times a week, it was not possible to get yield data in many cases. Individual yield records were kept on 8 plants in each plot of two fields, one of these fields had been sprayed with lime sulphur 1 to 50 and the other dusted with 200 mesh sulphur. The results are given in Tables 3 and 4.

TABLE 3. YIELD OF TOMATOES IN POUNDS FROM PLOTS SPRAYED WITH LIME SULPHUR ONE PART TO 50 PARTS OF WATER

Treatment	Average weight per plant in pounds	Average weight of fruits	Yield per acre in pounds	Increase in pounds per acre over check
Check	2.18	.66	5,934	———
1 spray	11.06	.095	30,105	24,171
2 sprays	12.27	.108	33,399	27,465
3 sprays	15.97	.148	43,470	37,536

There is some error in the record for the one spray plot as it was picked Sept. 20 without weights being taken.

TABLE 4. YIELD OF TOMATOES IN POUNDS FROM PLOTS DUSTED WITH 200 MESH SULPHUR

Treatment	Average weight per plant in pounds	Average weight of fruits	Yield per acre in pounds	Increase in pounds per acre over check
Check	2.18	.121	5,934	———
1 dust	7.59	.161	20,664	14,726
2 dusts	5.67	.190	15,434	9,500
3 dusts	5.9	.190	16,060	10,126

This record is not complete for the season as on Sept. 21, on account of a threatening freeze, a large picking of both ripe and green fruit was removed without weighing. As the treated plots had grown much better throughout the season, and had set much more late fruit, the loss of this picking affected the yield of the dusted plots more than that of the check. This field was not as heavily infested as the one from which the data in Table 3 were taken.

It will be noted that both the lime sulphur sprays and the sulphur dusts gave a very marked increase in yield. Considering the differences in initial infestation it is felt they were equally effective. This is borne out by observations on their use in a number of other plantings. The difference in quality was as marked as that in yield. Very little of the fruit from the checks was marketable on account of inferior quality and lack of size.

SUMMARY.—The feeding of tomato psyllid nymphs on tomatoes produces a definite disease condition known as psyllid yellows. An upward rolling of the older leaves, puckering of the younger leaves, with a general loss of the natural green color with some purpling of veins and a general stunting of the plant are some of the symptoms. The fruits are reduced in size and quality. Lime sulphur spray and sulphur dusts have a distinct repelling effect upon tomato psyllid adults and a lethal effect upon the nymphs. Plants freed of the insect show a marked tendency to recover and give a marked increase in yield and quality of fruit.

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3. LIST, GEO. M. 1918. Test of insecticides. Colo. State Entomologist Cir. 26, pp. 36–45.
4. ———— 1934. Lime sulphur for tomato psyllid control, Colo. Exp. Sta. Bul. 411.
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STUDIES OF THE REACTIONS OF POTATO APHIDS TO SPRAYED AND UNSPRAYED POTATO LEAVES

By JOSEPH B. MOORE, *Cornell University, Ithaca, N. Y.*

It has been shown that the Pink and Green potato aphid, *Macrosiphum solanifolia* Ashm., increases in numbers on potatoes which have been sprayed with Bordeaux mixture. Taylor and Blodgett (10), while conducting potato spraying experiments in New York State, observed that, at higher pressures, the number of aphids increased, while the number of leaf hoppers decreased. Bordeaux 5–5–50 was used in these experiments. The counts obtained were as follows:

Unsprayed	20
Sprayed at 200 lbs	61
Sprayed at 300 lbs	82
Sprayed at 400 lbs	92

Many other workers, conducting potato spraying experiments, find that the numbers of aphids increase on Bordeaux sprayed plants as compared with unsprayed plants. De Long (1) has demonstrated that Bordeaux mixture materially reduces leaf hopper populations on potato plants.

Aphids are a major pest of potatoes in many instances, causing damage both by their disease dissemination and direct injury to potato plants. Obviously, if present spraying formulae tend to increase the numbers of these pests on potato vines, any modification of materials, to reduce this tendency, would be of practical value. Therefore it would be of interest to determine why increased numbers of aphids occur on Bordeaux sprayed plants as compared with unsprayed plants.

There are several tentative explanations for this. There are the effects of the spray on the succulence of the plant tissues; there are the fungicidal actions of the Bordeaux mixture on the fungous diseases attacking aphids; there are the possible changes in temperature and humidity at leaf surfaces due to the increased rate of transpiration, as shown by Wilson and Rummels (11) in their recent paper.

For several reasons the phototropisms of aphids was taken as one of the most logical angles from which to approach this problem. The distinct color change in the Bordeaux sprayed plants is very noticeable. Insect phototropic responses are known to be affected by different

colors. Folsom (2) showed fairly conclusively that the initial infestations of the cotton aphis are due to the positive phototropic reaction of the winged females to white substances, such as calcium arsenate, calcium carbonate, starch and flour. A heavy infestation is later built up by destruction of Hymenopterous parasites upon emerging in the presence of the arsenical. Hess (3) showed that the order of effectiveness in rate of movement is green, yellow, blue, and red with sixteen different species of insects. Imms (4) states that color perception among insects does not include the whole spectrum visible to human beings, and, at the same time, involves the appreciation of wavelengths entirely invisible to us.

EXPERIMENTAL.—The question arose as to whether or not aphids increase faster and are therefore present in larger numbers on sprayed plants as compared with unsprayed plants. Potato plants of the same age, free from aphids, were placed under cages. One was sprayed with Bordeaux mixture while the other was left unsprayed. Four stem mothers as near the same age as possible, were introduced in each of the cages. At the end of two weeks the entire population in each cage was counted. This experiment was replicated eight times. The results are presented in Table 1.

TABLE 1. COMPARATIVE APHID POPULATIONS ARISING FROM EQUAL INITIAL NUMBERS ON SPRAYED AND UNSPRAYED POTATO PLANTS

Replications	No. of aphids on sprayed plants	No. of aphids on unsprayed plants
1	1305	1325
2	1310	1304
3	1324	1300
4	1306	1311
5	1298	1300
6	1325	1320
7	1310	1305
8	1306	1313

Average difference 2.25
Difference to be significant 25.045

It may be seen from the above table that aphids do not increase in numbers when allowed to develop on sprayed plants as compared with unsprayed plants, under greenhouse conditions. Apparently, some factors influencing the insects' choice of plants would explain more logically the greater numbers found on sprayed plants in the field.

A second experiment was conducted to determine whether or not differences existed in the response of the insect to light reflected from sprayed leaves compared to unsprayed leaves. One large center top hole and four smaller ones in the sides were bored in a cardboard cheesebox, filled with paraffin, as shown in Fig. 64. The holes in the sides were fitted with glass tubes, so as to have the bottom of the tubes flush with the floor of the chamber in the center of the box. The whole apparatus was blackened inside. The four glass tubes, six inches in length, were made opaque, and inserted in the box at right angles to each other. One-half inch from the end of each tube, sprayed and unsprayed leaves were placed at alternate tubes. Exactly centered above this box was a 300 Watt Mazda bulb, adjusted to deliver exactly 450 candle power or 465 zonal lumens at each leaf surface.

The effects of temperature, humidity and gravity were held constant and the experiments were run in a dark room. The aphids were brought from the greenhouse, shaken from a leaf into the center chamber and the cork put in place. The light was turned on and the aphids in each of

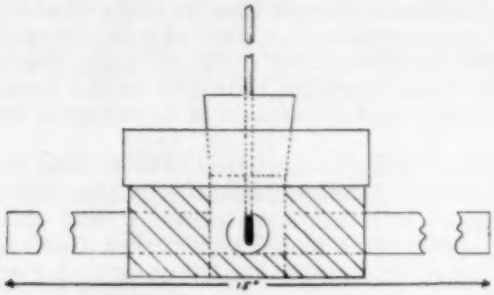

FIG. 64.—Side view of phototropism apparatus, showing center hole and side holes with tubes inserted.

the tubes were counted at the end of three minutes. Results of preliminary tests showed no difference between winged and wingless adult females in their reaction. Therefore wingless forms were used. The leaves were changed from one tube to another between each test. The experiment was replicated sixty times. The results were then calculated in units of 100 insects, giving a total of six replications of 100 insects each. These results are shown in Table 2.

TABLE 2. COMPARATIVE NUMBERS OF APHIDS RESPONDING TO LIGHT REFLECTED FROM SPRAYED AND UNSPRAYED POTATO LEAVES

No. coming to sprayed leaves	No. coming to unsprayed leaves
78	22
76	25
74	30
62	37
78	24
77	34
Total.....445	172
Average..... 74	28.6

Mean difference 45.5
Difference to be significant 9.47

From these data, it is apparent that the aphids were definitely attracted in larger numbers to the sprayed leaves under the conditions of the experiment. The question then arose as to whether or not they were attracted by the wavelength of the reflected light or by the intensity of the reflected light. Imms (4) states that light perception in bees embraces rays whose wavelength lies between 6500 A° and about 3000 A°. There is a marked preference for rays of the shorter wavelength. He also states that there is a theory that some plants reflect ultra-violet rays perceptible and attractive to insects. Lutz (6) states that ultra-violet reflections from flowers, which Richtmeyer (9) definitely demonstrated, is as important in discussions of the relation

between floral colors and insects as any other, since insects are photopositive to ultra-violet. Lutz and Richtmeyer (7) also state that insects react strongly to wavelengths in the violet end of our spectrum. *Drosophila melanogaster* reacts promptly and definitely to ultra-violet rays of such a low intensity as to produce no fluorescent sensation to the men conducting the experiment. Moore and Cole (8) show that the rate of response of an organism to light is proportional to the logarithm of

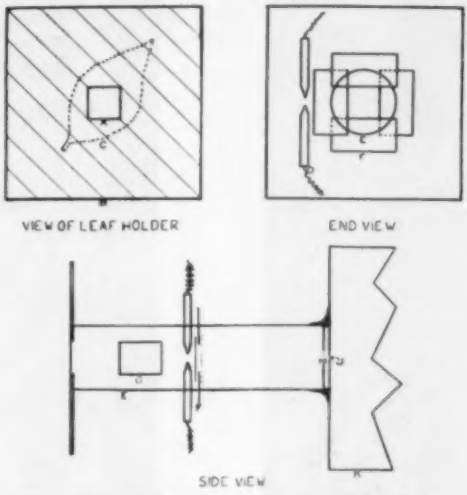

FIG. 65.—Apparatus for spectral analysis of reflected light. A, exposed area of leaf, C. B, black velvet covering leaf except portion A. D, brass arc. E, mailing tube 6 inches long. F, black paper baffles. G, window cut in side of mailing tube, H, lens of spectrograph, K. J, slit of spectrograph, K.

the intensity of the illuminations. Laurens and Hooker (5) state that the time required for reaction is inversely proportional to the intensity of the light. With these facts in mind, further analysis on the reactions of aphids in previous tests offered considerable interest.

An attempt was made to demonstrate the differences in the wavelength and relative intensity of the reflected light from sprayed potato leaves as compared with unsprayed leaves. The diagram in Fig. 65 shows the set up used in this experiment. A brass arc was used arbitrarily because it was easy to obtain and gave a good spread of spectral lines from ultra-violet to infra-red (2100 to 7000 A°.) The adjustment of the baffles permitted only light reflected from the leaf surfaces to strike the slit of the spectrograph. An exposure of exactly five minutes was given to the sprayed and unsprayed leaves, and the black velvet alone. Then a short exposure of the arc itself was made. Since all the exposures were

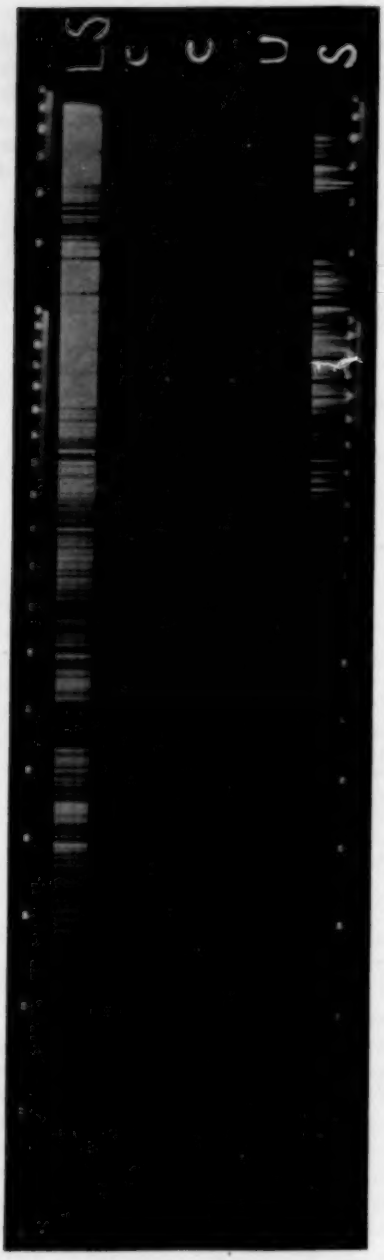

FIG. 66.—Wavelengths of reflected light: S, wavelengths reflected from sprayed leaf; U, wavelengths

FIG. 67. — Wavelengths of transmitted light: S, wavelengths of light transmitted

on the same plate, with the same set up, including the slit width, the development was the same for all, and comparative measurements of both wavelength and intensities were possible.

Upon examining the plate (Fig. 66) it is evident that there was no difference in the wavelengths of the light reflected from the two leaf surfaces. There was, however, more intense light reflected from the sprayed leaf surface. A plate was made of the transmitted light, by interposing the leaves between the arc and the slit of the spectrograph. This plate (Fig. 67) shows that more of the longer wavelengths are absorbed by the sprayed leaf. Therefore there is a possible small tempera-

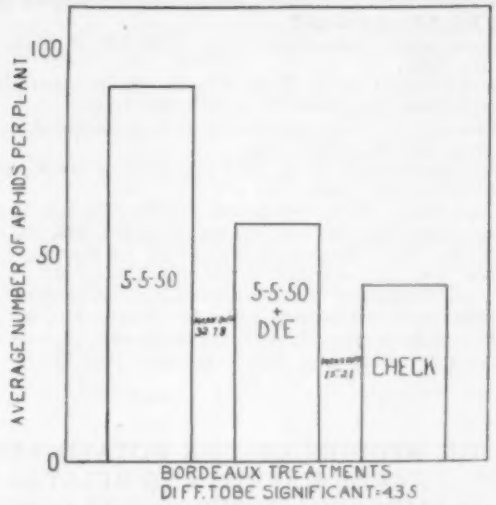

FIG. 68.—Aphid populations with different Bordeaux treatments. 5–5–50. . . 90.4; 5–5–50 plus dye. . . 57.3; check. . . 43.5.

ture difference at the leaf surface. This is of interest in connection with the increased rate of transpiration of potato plants sprayed with Bordeaux as reported by Wilson and Rummels (11).

A preliminary field experiment was conducted during the past summer using Bordeaux mixture 5–5–50 alone and dyed with Fast Green. Four row plots, including checks, were treated with a power sprayer and replicated alternately across the field. Three weeks after the applications were made, all the aphids on every tenth plant of the middle row of each plot were counted. A total of 5715 aphids was recorded. The summarized results are presented in Fig. 68.

There was a marked reduction in the numbers of aphids on plants sprayed with the dye combined with Bordeaux mixture. There were,

reflected from unsprayed leaf; C, wavelengths reflected from black velvet; L S, wavelengths of light source.

through sprayed leaf; U, wavelengths of light transmitted through unsprayed leaf; L S, wavelengths of light source.

however, fewer aphids on unsprayed vines than on the dyed vines. Apparently the dye did not entirely mask the effects of the Bordeaux. The experiment is primarily of interest in suggesting further possible studies of practical modifications of Bordeaux formulae for potato spraying.

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HIBERNATION STUDIES OF THE POTATO LEAFHOPPER (*EMPOASCA FABAE* HARRIS) AND RELATED SPECIES OF EMPOASCA OCCURRING IN OHIO

By D. M. DELONG and J. S. CALDWELL

Although textbooks and other published records of the biology of *E. fabae* indicate that this insect hibernates as an adult, to the best of our knowledge there are no authentic records or data for these conclusions. The senior author has already pointed out the fact that no positive data have been secured[1] and that all specimens which were secured under hibernating conditions and which have previously been thought to be *fabae* have been mistaken for other species where it has been possible to make identifications.[2]

In view of the manner of the appearance of this pest in the spring there are three possibilities which might be offered in explanation of the wintering condition. First, that the adult passes this period in hibernation; second, that it spends the winter in the egg stage upon a wild host plant and develops to maturity before migrating to economic food plants and, third, that it cannot live over winter in the northern states and migrates from southern areas in the spring. The evidence that has

[1] Jour. Eco. Ent. 24: 1220–1221, 1931.
[2] U.S.D.A. Bul. 231:2, 1931.

been obtained by field study and observations during the past eight years in support of each of these possibilities will be presented briefly.

In regard to the first possibility, adult hibernation, the evidence which has been obtained has all been negative. During the winters of 1926, 1927 and 1928 attempts were made to carry a large number of adult leafhoppers through the winter in hibernation quarters. Fallen leaves, crop remnants, and similar debris in protected places were used as a hibernation medium and not a single individual survived during these three seasons.

Beginning with 1927 attempts were made to find or recover *E. fabae* in hibernating quarters under natural conditions. To date these attempts have proven unsuccessful and all specimens of Empoasca that have been recovered in hibernation have proven to be some other species. *E. fabae* is by far the most abundant in numbers of any species of Empoasca occurring in the eastern U. S. and if it hibernates successfully under conditions similar to other hibernating leafhoppers, it should be found by chance at least, more quickly than any other species. But investigation has shown that *E. recurvata, infusca, birdii, curvata, bicorna, spira, hama, lata, recta, ditata, vergens, distracta, pyramidata* and one or two other species not yet described, all of which occur much less abundantly, have been found along with hibernating species of Erythroneura in Ohio during January, February, March and April but no specimens of *fabae* have been found either in these or similar habitats. Also if this insect passes the winter as an adult one would expect that it would come out of hibernation at approximately the same time as other hibernating leafhoppers such as species of Erythroneura, Dikraneura, Agellus, Agallia, Euscelis, Phlepsius, Thamnotettix, Platymetopius, Polyamia, Deltocephalus, and other species of Empoasca. However, observations have shown that the earliest specimens of *E. fabae* appear at least a month later than these hibernating species come out of winter quarters.

Several records have been published regarding the early occurrence of the adults of *E. fabae* upon wild host plants in the spring when they have supposedly come from hibernation. These observations and records have been made by investigators who have admitted that they did not use the genital characters to identify their material and could not distinguish *E. fabae* from the other species of Empoasca which are closely related, which have the same external appearance, and which normally live upon these wild hosts. Also an examination of specimens occurring in Ohio upon dock and other wild host plants in the spring has revealed the fact that all of them are specimens of *E. erigeron, E. bifurcata* or *E. recurvata*.

The earliest records of *E. fabae* for Columbus are late May although the real migration does not occur until about the middle of June. In 1933 for instance the first specimens found were taken on May 22 while the heaviest migration occurred on June 8 to 11. In 1932 the migration occurred on June 14 to 20.

The second possibility is that the insect overwinters in the egg stage upon a wild host plant and completes its development, then migrates to economic plants later in the spring. The time of its first appearance in the field would be a factor favoring this possibility. As indicated above,

it occurs in the field much later than hibernating material. But detailed search in the field during the early season for a period of eight years upon all types of wild host plants has failed to give any positive evidence that *E. fabae* winters in the egg stage upon these wild host plants. *E. erigeron* and *E. bifurcata* are known to pass the winter in this way and the eggs hatch in late April or early May. Although these species occur in very small numbers as compared to *E. fabae*, they are found commonly in the spring upon wild host plants in the nymphal stage, but nymphs of *fabae* cannot be found. If *E. fabae* overwinters as an egg, in view of its great abundance later in the season, it should be found easily early in the season in the nymphal stage either on wild or cultivated host plants. Examination of crop remnants has also failed to give any positive evidence regarding the overwintering as an egg.

In view of the fact that specimens of *E. fabae* cannot be successfully hibernated nor found in hibernation and that no evidence can be obtained regarding the passing of the winter in the egg stage upon either wild or cultivated host, and in view of the late appearance in the spring of the adults in great abundance, there is a strong possibility of the third explanation, that the insects pass the winter or survive only in areas of milder climate and migrate in Ohio and similar states as adults at a later date. The only evidence for this is the strong negative evidence presented in the other two possibilities and the fact that they appear in cultivated fields exactly as other migrating leafhoppers appear in other areas on economic crops. The migration flights are usually marked by the abrupt appearance of large numbers in cultivated fields and late in the season, apparently migrating from a breeding ground elsewhere.

Material taken in Florida and in the Gulf states show definitely that *E. fabae* breeds in these areas on alfalfa and similar crops during the winter and that the populations become quite large in March and April.

Replying to queries, it was stated that in cold seasons, the insect appears first on alfalfa and then on potatoes, that it comes abundantly to trap lights, that it winters in the Gulf states and that there is no conclusive data for more northern sections.

DERRIS AND OTHER INSECTICIDES FOR THE CONTROL OF THE MEXICAN BEAN BEETLE

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Experiments to determine the effectiveness of various insecticides for the control of the Mexican bean beetle (*Epilachna corrupta* Muls.), which were begun several years ago in Ohio and Virginia and upon which a preliminary report was made two years ago,[1] were continued in 1933 and 1934. Recently special attention has been given to derris root, used

[1]Howard, N. F., Brannon, L. W., and Mason, H. C. 1933. Insecticides for the control of the Mexican bean beetle. Jour. Econ. Ent. 26: 123–128.

both in dust form with various carriers and in water suspension, since derris residues have been considered less harmful to human beings than arsenical or fluorine residues.

This report summarizes briefly the more important conclusions drawn from 19 experiments comprising over 16 acres, 913 plots, and 1,824 applications in Ohio, and 16 experiments comprising 14 acres, 706 plots, and 1,121 applications in Virginia, chiefly on the Eastern Shore. Both power and hand machinery was used, and yields were recorded in a few instances. Three major types of beans were treated, namely, snap, lima, and horticultural. The infestation was very heavy in Ohio during both years and in Virginia during 1934, untreated plots being defoliated by the beetle during or at the close of the experiment.

DERRIS SPRAYS.—Finely ground derris root in water[2] appears to be one of the best insecticides ever tested for the control of the Mexican bean beetle. All tests with derris in water were conducted in 1934. According to the results obtained in these tests, no spreader or sticker is required; in fact, better results were usually obtained when the material was used alone than when it was used with powdered soap. Moreover, a commercial mixture of derris root and soap, used as a spray, did not give such good results as the derris root alone. In general, a lime-casein adhesive or bentonite-sulphur in conjunction with derris did not improve control. Derris stays in suspension and sticks well, even to cabbage leaves, and has about as lasting an effect as any material yet tried.

Very good control was obtained at dosages of 1½, 2, and 2½ pounds of derris of 4.4 per cent rotenone content in 50 gallons of water (rotenone content of sprays[3], 0.015, 0.02, and 0.026 per cent, respectively), but, on the basis of results obtained to date, it is possible that the practical recommendations should specify 2 or 2½ pounds to 50 gallons of water. Powder with a different rotenone content may be used in proportion to that content. One pound of derris powder of 4.4 per cent rotenone content to 50 gallons of water, although toxic to the insects present, did not afford sufficient residual effect. At the dosages recommended there is little or no saving of derris as compared with the use of dust mixtures, but the better control and the increased residual effect obtained with the water suspension make its use as a spray preferable. After treatment with either derris dusts or sprays, large numbers of dead and morbid beetles and larvae were observed beneath the plants. Laboratory tests indicate that derris dusts and sprays are toxic to the eggs of the bean beetle.

The water suspensions of the ground derris root are superior to the extracts of either derris or pyrethrum or a combination of the two. The difference in costs between derris extract and ground derris root in water is not great; the combined derris-pyrethrum extract is far more expensive. The increase in residual or lasting effect of the ground root over that of the extract is marked. In Ohio very poor control was obtained in both 1933 and 1934 on bush lima beans treated eight times and

[2]Osburn, M. R. 1934. Experiments with rotenone and derris to repel the Japanese beetle (*Popillia japonica* Newm.). Jour. Econ. Ent. 27: 293.

[3]Rotenone content of sprays figured on the weight of water at 59° F.

on French horticultural beans treated six times with a commercial derris extract (1.5 per cent rotenone according to the producer) at the rate of 1 part in 400 parts of water, but excellent control was obtained in 1934 when the ground root was used in water. On snap beans, which mature sooner, the extract, and also a combined pyrethrum-derris extract (1 to 400), gave good results in Virginia, but the foliage was almost consumed at the close of the experiment, showing a lack of residual effect.

DERRIS DUSTS.—Ground derris root with a carrier used as a dust has given very promising results. The general conclusion from a large number of applications is that a dust should contain from 0.5 to 0.75 per cent of rotenone (10 pounds of 5 per cent derris to 90 pounds of carrier or 15 pounds of 5 per cent derris to 85 pounds of carrier). Of six carriers and combinations of carriers, comprising talc, tobacco dust, infusorial earth, ground marc (extracted pyrethrum flowers), inert clay, and hydrated lime, talc in general proved to be the best. Very good control of the bean beetle was obtained when 20 to 25 pounds was used to the acre. Hydrated lime in some instances appeared to reduce toxicity and should not be recommended. The selection of the best carrier for use in dust mixtures will require more experimentation.

Commercial derris dusts containing 0.45 to 0.55 per cent of rotenone gave as satisfactory results as the home mixtures of the same rotenone content, but the home mixtures are, of course, more economical if costs of mixing are disregarded.

The operators who made the applications of derris sprays and dusts experienced an annoying irritation to the tender skin in the pubic region and between the buttocks. The skin was so affected that it finally peeled off. No further trouble was experienced after the handling of the dusts and sprays was discontinued. Derris dusts also irritate the nose and throat of the operator and in one instance affected the voice when dusts were being prepared in the laboratory.

PYRETHRUM.—Used as a dust, with equal parts of tobacco dust, this material was not so good as derris dusts containing 0.5 to 0.75 per cent of rotenone. In water suspensions at 2½ pounds to 50 gallons, with or without 1 pound of powdered soap, there was almost no control. The addition of pyrethrum to derris in water was of no benefit.

Pyrethrum extracts are toxic and kill all the insects touched, but residual effects appear to be lacking, and they are too expensive to be generally recommended. During 1933 very poor control was obtained in Ohio on bush lima beans after eight applications, and on French horticultural beans after six applications of a combined pyrethrum-derris commercial extract used at the rate of 1 part to 400 parts of water by volume. (See last paragraph of discussion under "Derris.")

HELLEBORE.—Hellebore was tested as an undiluted dust in 1933. Control ranged from very poor to medium, and its use was discontinued.

CRYOLITE.—The favorable results with synthetic cryolite reported two years ago have been corroborated. Natural cryolite has also been tried. In general, when used as a spray, the synthetic material was slightly superior, but either may be recommended at a dosage of 3 pounds to 50 gallons of water. In most of the experiments the synthetic compound

when used as a dust was not very satisfactory, but when mixed with fine dusting sulphur—60 pounds of cryolite to 40 pounds of sulphur—very good results were obtained in one experiment in Ohio, while only fair results were obtained in a repetition of the experiment. In one experiment a 60–40 mixture of cryolite and wheat flour gave results almost as good as the cryolite-sulphur mixture. Mixtures with other carriers in the same proportions did not give good results, although in one experiment in Virginia very good results were obtained with talc and with tobacco dust. In general, derris-dust mixtures gave better results at lower costs, since more dilute cryolite dusts were not satisfactory. Cryolite has not injured foliage during the last five years and has that advantage over the other stomach poisons, magnesium arsenate and calcium arsenate. As a spray at 3 pounds to 50 gallons of water it appears to be slightly superior to magnesium arsenate at 2 pounds to 50 gallons.

Barium Fluosilicate (*80 per cent Commercial Mixture*).—As now prepared and sold commercially, this material gives better results than formerly. In most of the tests it was used at the rate of 5 pounds to 50 gallons of water. It gave satisfactory results in one series of tests when used at the rate of 3 pounds to 50 gallons of water, and when used as a dust either undiluted or with 20 pounds of wheat flour to 80 pounds of the commercial product. During 1933 rather severe foliage injury resulted from the use of some material bought in 1932 at the rates of 3 and 5 pounds to 50 gallons of water.

Potassium Hexafluoaluminate. — Potassium hexafluoaluminate did not give such satisfactory results as synthetic cryolite. There appears to be no advantage in using this material instead of cryolite.

Sodium Fluosilicate.—Sodium fluosilicate 1 part and wheat flour 2 parts gave good control of the bean beetle, but severely injured the foliage and caused a reduction in yields in Virginia.

Magnesium Arsenate.—This material is still the most economical insecticide, since 2 pounds to 50 gallons of water is sufficient. At times in recent years foliage has been injured, but as a rule the injury is not of any great consequence. Recently there has been sold a brand which seriously injures bean foliage. Growers who are able to obtain the same brand that they have used in the past without foliage injury can profitably continue its use, but recent experiments indicate that better results and greater yields may be obtained with derris or cryolite. In view of these facts derris or cryolite is now recommended in preference to magnesium arsenate.

Phenothiazine.—In Ohio during 1934 phenothiazine (thiodiphenylamine)[4] at the rate of 3 pounds to 50 gallons of water gave good control in two experiments. In one experiment when tested at the rate of 1 pound to 50 gallons of water, the control given was only fair. No noticeable injury to bean foliage resulted.

Cuprous Cyanide.—When used either at 2 pounds or 3 pounds to 50 gallons of water, fair control was obtained with cuprous cyanide and the residual qualities were very good. No appreciable foliage injury resulted

[4]A synthetic organic compound with the formula $NH(C_6H_4)_2S$, prepared commercially according to the specifications of the insecticide division.

during 1934 when the powder was used, but during 1933 a paste gave moderate foliage injury.

SULPHUR.—Some protection was afforded when a flotation-sulphur dust or a fine dusting-sulphur dust was applied or when flotation-sulphur paste was applied at the rate of 8 pounds to 50 gallons of water. The material is not toxic enough to render complete control consistently, but at times good foliage protection is obtained. When used with stomach poisons or with derris, no benefits resulted in a number of tests, whereas in others the yields of beans were increased. More work should be done along this line, since sulphur is known to be of value for the control of the red spider and the potato leafhopper on beans, and occasionally these pests are present with or following bean-beetle infestations.

When bentonite-sulphur was used with derris in water, sometimes control was better than with derris alone, but at other times it was not so good. More experimentation is needed here also.

NICOTINE.—Nicotine dusts containing 2 per cent nicotine in a bentonite-sulphur carrier, and nicotine-bentonite-sulphur sprays at the rate of 1 pint nicotine sulphate and 3 pounds bentonite-sulphur to 50 gallons of water, gave very poor results and indicated that these mixtures are not satisfactory stomach poisons for the control of the Mexican bean beetle.

ANABASINE SULPHATE.—Anabasine sulphate was used under both laboratory and field conditions in Ohio during 1933. At a dilution of 1 part in 100 parts of water the control was poor and there was moderate injury to bean foliage. Such unfavorable results were obtained that the use of the material was discontinued.

EFFECTS OF CONSTANT LIGHT, TEMPERATURE, AND HUMIDITY ON THE RATE AND TOTAL AMOUNT OF OVIPOSITION OF THE BEAN WEEVIL, *BRUCHUS OBTECTUS* SAY.

By HENRY MENUSAN JR., *Ithaca, New York*

Temperature and humidity have been shown to have marked effects[1] on the duration and viability of the different stages of the bean weevil. It is of great interest to determine what effects such external factors as light, temperature and humidity might have on the rate and total amount of oviposition. There are numerous observations on record of effects of climate on oviposition. As Richardson,[2] in his summary of oviposition response of insects, has pointed out very few attempts have been made to analyze the oviposition reaction of insects. This paper summarizes some of the effects of constant light, temperature and humidity on the rate and total amount of oviposition of the bean weevil, *Bruchus obtectus* Say.

[1]Menusan, H. Jr. Effects of temperature and humidity on the life processes of the bean weevil, *Bruchus obtectus* Say. Ann. Ent. Soc. Amer. *27*:515–526. 1934.

[2]Richardson, C. H. The oviposition response of insects. U. S. Dept. Agr. Bul. 1324. 17 pp. 1925.

METHODS.—Preliminary experiments indicated that females reared on different varieties of beans, might not oviposit at the same rate or give the same number of eggs. Females separated from the males soon after copulation took place laid about the same number of eggs as the females kept with the males. After one week however, there was a larger proportion of unfertilized eggs deposited by the separated (fertile) females. Virgin females lay only one fifth the number of eggs of fertile females. All the eggs deposited by virgin females collapse soon after deposition.

Females reared from red kidney beans oviposited more often on and among red kidney beans than on any other beans with the possible exception of lima beans. The gravid female with the choice of five varieties of beans and the garden pea to oviposit on apparently preferred to oviposit on the different seeds as follows: lima bean, red kidney bean, white kidney bean, pea bean, black valentine bean and least of all the garden pea. The experiment was conducted in the dark under controlled conditions so that if chance were the only factor the number of eggs deposited on the different seeds should be approximately equal. It is not known whether weevils reared from a different bean variety would still show the same order of preference.

The technique finally chosen was to rear the bean weevils in red kidney beans in darkness in a constant temperature cabinet with the relative humidity at fifty per cent. Five females with an equal number of males that had emerged within 20 hours were placed in 50 cc. vials or Erlenmeyer flasks containing five red kidney beans. Previous to the introduction to the weevils the beans were maintained at the given humidities until they became at equilibrium with the environment. The containers, covered with bolting cloth to prevent the adults from escaping, were placed in constant temperature baths and the eggs deposited were removed and counted daily. With the constant humidities, air of the proper humidity was passed through the containers at the rate of one liter per hour. The method of controlling the temperatures and humidities has previously been described.[1] All experiments with constant temperatures and humidities were carried on in darkness.

The results on light were run in duplicate while the temperature and humidity results are the summary (20 females) of four tests on different generations of weevils using five females per test per point. The mean result of each experiment was treated statistically to determine the confidence that could be placed on the results. The variance[2] method of analysis was used and differences equal or greater than twice the standard error of the difference between means were considered significant. This gives odds of 21:1 that the occurrence of so great a difference is not due to chance.

EXPERIMENTAL RESULTS

LIGHT.—The newly emerged adults are negatively phototrophic, old adults however, or females after oviposition reverse their phototrophic response. As might be expected from their phototrophic re-

[2]Fisher, R. A. Statistical methods for research workers. 3rd ed. pp. 178–237. 1930.

sponse, light reduces the number of eggs deposited by the females. The reduction is proportional to the light intensity with white light (Table 1). Red light, to the bean weevil, is apparently equivalent to darkness since it has no effect on egg production. The results with light were obtained when the bean weevils were two and a half feet from the constant light source. The temperature difference between the check (in

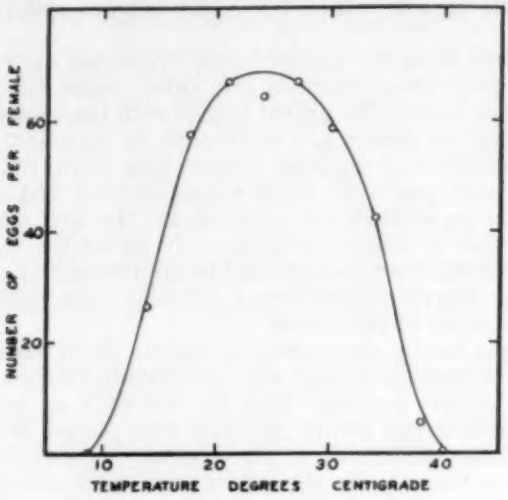

FIG. 69.—Total number of eggs deposited by the bean weevil at different constant temperatures on red kidney beans in darkness with the relative humidity at 90 per cent.

darkness) and the most intense light was less than 0.5°C. which does not account for the difference in oviposition (Table 1).

TABLE 1. THE EFFECT OF CONSTANT LIGHT ON THE TOTAL OVIPOSITION OF THE BEAN WEEVIL AT 27° C. AND 90 PER CENT R. H.

Quality of light	Approximate intensity C. P.	Average number of eggs per female
White light, from inside frosted lamp	120	29.6
White light, from inside frosted lamp	50	34.6
White light, from inside frosted lamp	15	41.4
Red light, from clear ruby lamp	15	66.6
Check, in darkness	—	67.0

TEMPERATURE.—Temperature has a marked effect on both the rate and total amount of oviposition. The lower the temperature, between 40°, and 13°, the longer the oviposition period (Table 2 and Figure 70). The number of eggs deposited per female increases as the temperature is decreased from 40° to 24°; while from 24° to 14°, the number of eggs decreases as the temperature. At a temperature of 8.7° the females died without ovipositing. If the greatest number of viable eggs in the shortest period of time is considered to be optimum for

oviposition then 27° is the optimum temperature. A greater number of eggs might be laid by females at 24° than at either 27° or 21° as illustrated by Figure 69. The deviation of the point at 24° from the curve is within the normal variation to be expected from chance.

Any marked deviation from the optimum temperature resulted in a decrease in the quantity of eggs laid. Females at high temperatures, 30°

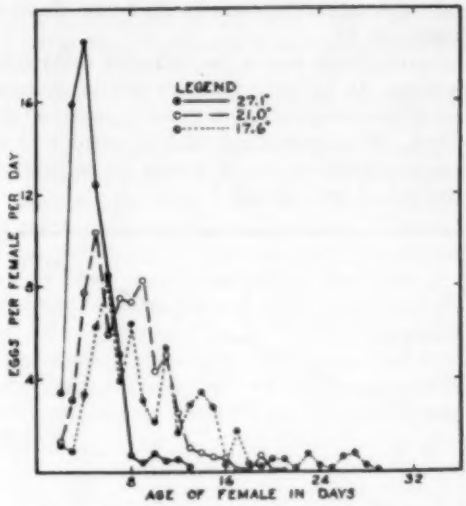

FIG. 70.—Rate of oviposition of the bean weevil at different constant temperatures with the relative humidity at 90 per cent on red kidney beans in darkness.

or above, deposited more unfertilized eggs than the females at lower temperatures. An egg collapsing or drying out within a day after deposition is considered unfertile. At moderate or low temperatures only one per cent of the eggs appear to be unfertilized, while at 30° three per cent collapsed and at 38° the percentage is increased to thirty-one and at 40° all eggs are killed. The quantity of eggs was reduced to two-thirds

TABLE 2. OVIPOSITION OF BEAN WEEVILS IN DARKNESS ON RED KIDNEY BEANS AT DIFFERENT CONSTANT TEMPERATURES WITH THE RELATIVE HUMIDITY AT 90 PER CENT

Temperature °C.	Duration of oviposition in days	Total number of eggs	Average number of eggs per female
8.7	—	none	0.0
13.9	68	533	26.6[1]
17.6	28	1159	57.9
21.0	20	1343	67.1
24.2	17	1287	64.3
27.1	12	1341	67.0
30.1	11	1179	58.9
34.0	12	850	42.5
38.2	6	106	5.3
40.2	1	5	0.2

[1]Differences of 10.2 eggs in the number of eggs oviposited per female are probably significant.

the normal for 27° and twenty per cent of those deposited were not fertile if the females were kept at 40° for one day before placing them at 27°. A two day exposure to 40° reduced the number to one-sixth normal of which seventy per cent were not fertile. Females exposed to either very high (40°) or very low (8°) temperatures, then placed at optimum temperatures deposited noticeably smaller and more spherical eggs than the typical oblong egg deposited at normal temperatures. These small round eggs were deposited after two days exposure at 40° and 60 days exposure at 8°.

At low temperatures there was a remarkable intermittent deposition of eggs by the females. At 14° five females would oviposit for from one to three days then either oviposit at a greatly reduced rate or not at all for one or two days. This repetition of high and low rate oviposition was repeated for about sixty days. It would be of interest to determine the egg laying interval of one female.

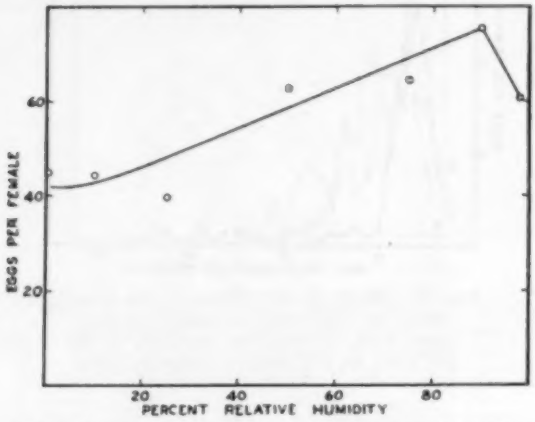

FIG. 71.—Total number of eggs deposited by the bean weevil at different constant relative humidities at a constant temperature of 25.2°C. on red kidney beans in darkness.

HUMIDITY.—The bean weevil lives in the dry environment of stored beans so that it might be expected that the relative humidity would have very little effect on oviposition of this particular insect. The time required for oviposition does not appear to be affected though the rate at which the eggs are deposited, varies with the different humidities. The highest rate and thereby the greatest number of eggs were deposited at 90 per cent relative humidity with the temperature at 25° (Table 3 and Figure 71). Increasing the relative humidity to 98 per cent decreased the number of eggs and reducing it to 75 or 50 per cent also decreased the number of eggs laid per female. Females at humidities varying from 1 to 25 per cent deposited about the same number of eggs but there was a marked increase in number if the relative humidity was increased to 50 per cent.

TABLE 3. OVIPOSITION OF BEAN WEEVILS IN DARKNESS ON RED KIDNEY BEANS AT A CONSTANT TEMPERATURE OF 25.2°C. AND DIFFERENT RELATIVE HUMIDITIES

Relative humidity per cent	Duration of oviposition in days	Total number of eggs	Average number of eggs per female
1	10	900	45.0[1]
10	13	888	44.4
25	12	796	39.8
50	11	1256	62.8
75	12	1289	64.4
90	11	1509	75.4
98	10	1217	60.8

[1]Differences of 11.8 eggs in the average number of eggs oviposited per female are probably significant.

SUMMARY.—Some of the factors affecting oviposition of the bean weevil have been discussed.

Constant white light reduces the number of eggs deposited by the weevils and the reduction is proportional to the light intensity. Temperature has a marked effect on both the time required for oviposition and the rate at which the eggs are deposited. The lower the constant temperature, from 40° to 13°C, the longer the oviposition period. The greatest number of eggs are deposited by females at 24° while the females at 27° have the highest rate of egg deposition. Few eggs were laid at 40° and none were deposited at 8.7°. The humidity of the environment did not appreciably affect the time required for oviposition. The greatest number of eggs were deposited by females at 90 per cent relative humidity. At low humidities (1–25% R. H.) fewer eggs were laid than at higher humidities.

OVICIDAL TESTS ON CERTAIN DIPTEROUS EGGS—WITH ESPECIAL REFERENCE TO THE ONION MAGGOT, *HYLEMYIA ANTIQUA* MEIG.

By J. P. SLEESMAN, *Ohio Agricultural Experiment Station*

During the past 3 years experimental work has been conducted in an effort to determine the toxicity of lubricating oil emulsions to the eggs of the onion maggot (*Hylemyia antiqua* Meig.). A boiled lubricating oil emulsion, prepared after the Government formula, from oil of standard specifications[1], several proprietary oil emulsions, and undiluted oil were used. The emulsions were diluted to give various percentages of actual oil and were used both alone and in combination with a 4–6–50 Bordeaux mixture. The purpose of this paper is to show the degree of toxicity exhibited by these materials to the eggs of the onion maggot, the black onion fly (*Tritoxa flexa* Wlk.), and the blowfly (*Sarcophaga sarraceniae* Riley). The discussion will be confined to the results of tests conducted in the laboratory and of field experiments in which the infestation was artificially introduced.

The plan in the laboratory was to conduct a series of experiments in which each treatment was replicated at least five times. In these tests potted onion plants were used, each pot being considered as a plot or

[1]110–115 seconds Saybolt viscosity at 100 degrees F.

replicate. The eggs were placed on the soil about the base of the plants, and conditions, insofar as possible, were uniform for all plots. Sufficient material was applied to the eggs to assure good coverage and an equal amount of water was applied to the check plots. The Bordeaux-oil emulsions in all tests, both laboratory and field, were prepared as follows: First, about half the required amount of water was added to the stock emulsion of oil; a stock solution of copper sulfate was added next, followed by the stock solution of lime; and, finally, sufficient water was added to give a 2 per cent oil concentration in the whole. The plants were dissected 7 days after they were sprayed and the number of larvae recovered in each treatment was noted.

In the field experiments all treatments were replicated not less than five times in randomized blocks, each plot consisting of 16 linear feet of row or approximately 150 plants. The infestation was introduced by placing the eggs in as nearly natural a manner as possible in the soil about the base of the plants. A small-sized camel's-hair brush was used in transferring the eggs to the plots. As soon as any of the plants began to show evidence of damage from maggots, they were dissected to determine the number of larvae feeding within them. These dissections were continued through the next 7 days.

The values appearing in the tables, excepting Tables 7 and 8, represent the actual number of larvae recovered in each replicate. The per-

TABLE 1. LARVAL ESTABLISHMENT IN LABORATORY PLOTS SPRAYED WITH BORDEAUX-LUBRICATING OIL EMULSIONS (25 EGGS PER REPLICATE), 1932

Treatment	Replicate and number maggots recovered 1	2	3	4	5	6	Total	Per cent recovered
Boiled oil emulsion 2 per cent 4–6–50 Bordeaux	22	22	21	18	18	21	122	81.33
Boiled oil emulsion 3 per cent 4–6–50 Bordeaux	15	15	20	24	19	20	113	75.33
Boiled oil emulsion 6 per cent 4–6–50 Bordeaux	16	21	13	18	21	25	114	76.00
Freemulsion 2 per cent 4–6–50 Bordeaux	23	22	19	23	19	21	127	84.66
Dendrol 2 per cent 4–6–50 Bordeaux	22	21	24	22	21	23	133	88.66
Check—Water	19	21	19	21	15	24	119	79.33

TABLE 2. LARVAL ESTABLISHMENT IN ARTIFICIALLY-INFESTED FIELD PLOTS SPRAYED WITH LUBRICATING OIL EMULSIONS (40 EGGS PER REPLICATE), 1933

Treatment	Replicate and number maggots recovered 1	2	3	4	5	6	7	8	Total	Per cent recovered
Boiled oil emulsion 2 per cent	25	18	3	22	17	31	26	40	182	56.87
Medina oil emulsion 2 per cent	34	20	27	26	33	27	35	31	233	72.81
Freemulsion 2 per cent	24	29	25	33	25	28	26	26	216	67.50
Check—Water	2	27	31	36	29	26	27	27	205	64.06

TABLE 3. LARVAL ESTABLISHMENT IN ARTIFICIALLY-INFESTED FIELD PLOTS SPRAYED WITH BORDEAUX-OIL EMULSION (100 EGGS PER REPLICATE), 1933

Treatment	Replicate and number maggots recovered 1	2	3	4	5	6	7	8	Total	Per cent recovered
Boiled oil emulsion 2 per cent 4–6–50 Bordeaux	61	58	52	28	48	45	53	43	388	48.50
Dendrol 2 per cent 4–6–50 Bordeaux	40	45	51	48	56	45	50	39	374	46.75
Check—No treatment	46	48	33	33	36	39	38	28	301	37.62

TABLE 4. LARVAL ESTABLISHMENT IN ARTIFICIALLY-INFESTED FIELD PLOTS SPRAYED WITH BORDEAUX-OIL EMULSION AND MERCURIC CHLORIDE (100 EGGS PER REPLICATE), 1933

Treatment	Replicate and number maggots recovered					Total	Per cent recovered
	1	2	3	4	5		
Boiled oil emulsion 2% 4–6–50 bordeaux	78	94	74	81	75	402	80.40
Dendrol 2% 4–6–50 bordeaux	82	78	88	77	68	393	78.60
Dendrol 6% 4–6–50 bordeaux	78	92	72	69	63	374	74.80
Mercuric chloride 1 oz. to 8 gal. water	0	0	0	0	0	—	—
Check—water	69	89	88	89	69	404	80.80

centage of establishment was determined upon the basis of the number of eggs used per replicate. In Tables 7 and 8 the number of eggs hatching and the percentage hatch are recorded.

The results of experiments, as summarized in Tables 1, 2, 3, and 4, indicate that the lubricating oil emulsions, when used alone and in combination with Bordeaux mixture, are not toxic to the eggs of the onion maggot. Increasing the actual oil content from 2 per cent to 3 per cent and to 6 per cent did not give a higher kill than the 2 per cent oil emulsion. Mercuric chloride, 1 ounce to 8 gallons of water, applied in sufficient quantity to saturate the soil thoroughly about the eggs, gave a very high kill. It will be noted, Table 3, that the rate of establishment in the check plots was consistently lower than that in the treated plots. It is a known fact that the amount of moisture in the soil influences the rate of larval establishment, and, inasmuch as water was not applied to the check plots in this particular experiment, the percentage of moisture in the soil was lower than in those plots sprayed with the oil emulsions.

Inasmuch as the various Bordeaux-oil emulsions are not toxic to the eggs and, further, because it is assumed that the oil factor is the active agent in the combination, recourse was made to the use of undiluted lubricating oil of the same specifications as that employed in the boiled oil emulsion formula. One cubic centimeter of oil was applied, drop by drop, directly to the eggs and subsequent examination showed them to be thoroughly covered with a film of oil and to appear translucent.

The results of these tests, as shown in Tables 5 and 6, indicate that undiluted lubricating oil is not toxic to onion maggot eggs, inasmuch as the rate of establishment in these plots was not significantly different from that in the check plots. It will be seen, Table 6, that a 1 per cent emulsion of tar acid oil (0.66 of 1 per cent tar acid oil), used as a reference material, was highly toxic to the eggs

Similar tests were conducted with two other dipterous eggs; namely, the black onion fly and the blow-fly. In addition to the usual treatment with Bordeaux-oil emulsion, other eggs were completely immersed in undiluted lubricating oil for varying periods of time (5 to 60 minutes) and the percentage hatch noted. The plan was to place the eggs in a watch glass and allow 10 cubic centimeters of oil to drop from a pipette directly on the eggs. After having been immersed for the desired length of time, they were removed and placed on soil contained in salve boxes, which were exposed to room temperature. The eggs were observed daily to determine the rate of hatch. In the cases of the onion maggot and the black onion fly, hatching was not completed until the third day after treatment; whereas the majority of the eggs of the blowfly hatched the following day.

TABLE 5. LARVAL ESTABLISHMENT IN LABORATORY PLOTS SPRAYED WITH BORDEAUX-OIL EMULSION AND UNDILUTED LUBRICATING OIL (100 EGGS PER REPLICATE), 1933

Treatment	Replicate and number maggots recovered								Total	Per cent recovered
	1	2	3	4	5	6	7	8		
Boiled oil emulsion 2%	71	70	76	50	47	76	77	78	554	69.25
Boiled oil emulsion 2% 4–6–50 bordeaux	66	51	62	71	70	81	78	82	561	70.12
Undiluted oil	80	63	81	60	69	73	62	68	556	69.50
Check—water	76	65	67	75	68	76	85	76	588	73.50

TABLE 6. LARVAL ESTABLISHMENT IN LABORATORY PLOTS SPRAYED WITH OILS IN 1934 (50 EGGS PER REPLICATE)

Replicate	Treatment and number maggots recovered			
	Boiled oil emulsion 2% 4–6–50 bordeaux	Undiluted oil	Tar acid oil emulsion 1%	Check—water
1	36	39	3	38
2	31	39	1	42
3	39	40	0	23
4	40	36	0	36
5	39	32	0	30
6	43	37	4	36
7	40	38	3	36
8	37	40	0	—
9	47	33	0	—
10	31	36	3	—
11	47	30	1	—
12	40	34	1	—
13	33	25	0	—
14	46	46	0	—
15	37	47	0	—
16	43	27	1	—
17	38	23	0	—
Total	667	602	17	241
Per cent recovered	78.47	70.82	2.0	68.85

TABLE 7. RATE OF HATCH OF BLOWFLY EGGS SPRAYED WITH BORDEAUX-OIL EMULSION AND UNDILUTED LUBRICATING OIL (50 EGGS PER REPLICATE), 1934

Treatment	Replicate and number eggs hatched						Total	Per cent hatch
	1	2	3	4	5	6		
Boiled oil emulsion 2% 4–6–50 bordeaux	46	49	45	50	47	49	286	95.33
Undiluted oil	49	45	47	48	44	47	280	93.33
Undiluted oil immersed 5 minutes	43	48	48	50	50	47	286	95.33
Undiluted oil immersed 10 minutes	49	47	49	50	48	47	290	96.66
Undiluted oil immersed 15 minutes	47	50	48	46	50	48	289	96.33
Undiluted oil immersed 30 minutes	50	50	48	44	46	46	284	94.66
Undiluted oil immersed 60 minutes	47	46	49	48	47	44	281	93.66
Tar acid oil emulsion 1%	0	3	1	4	1	3	12	4.0
Check—water	46	49	47	—	—	—	142	94.66

TABLE 8. PERCENTAGE HATCH OF BLACK ONION FLY EGGS SPRAYED WITH BORDEAUX-OIL EMULSION AND UNDILUTED LUBRICATING OIL (50 EGGS PER REPLICATE), 1934

Treatment	Replicate and number eggs hatched					Total	Per cent hatch
	1	2	3	4	5		
Boiled oil emulsion 2% 4–6–50 bordeaux	28	46	36	34	48	192	76.80
Undiluted oil	46	41	33	38	36	194	77.60
Undiluted oil immersed 15 minutes	36	43	42	38	44	203	81.20
Undiluted oil immersed 60 minutes	28	43	43	42	40	196	78.40
Check—water	38	42	40	28	32	180	72.00

It is of interest to note, Tables 7 and 8, that the eggs of the black onion fly and of the blowfly were not killed after immersion in undiluted oil for a period of 60 minutes and also, Table 7, that a 1 per cent emulsion of tar acid oil (0.66 of 1 per cent tar acid oil), used as a reference material, was very toxic to the eggs.

SUMMARY.—Lubricating oil emulsions, when used alone and in combination with Bordeaux mixture, were not toxic to the eggs of the onion maggot, the black onion fly, and the blowfly.

Increasing the concentration of actual oil from 2 per cent to 3 per cent and to 6 per cent did not increase the toxicity.

Immersing the eggs of the black onion fly and of the blowfly in undiluted lubricating oil for periods up to 60 minutes did not lower the rate of hatch.

THE BLACK GRAIN-STEM SAWFLY, *TRACHELUS TABIDUS* (FAB.), IN OHIO

By J. S. HOUSER, *Agricultural Experiment Station, Wooster, Ohio*

The black grain-stem sawfly, an insect of European origin, was found first in America at Riverton, N. J., some time prior to 1899. Fifteen years later, E. N. Cory reported an insect, which now is thought to have been this species, as damaging wheat in Maryland. In 1918 the attention of the Bureau of Entomology, of the United States Department of Agriculture, was directed to damage to wheat caused by this insect at Gaithersburg, Maryland.

Investigations were started at Gaithersburg by A. B. Gahan, of the Bureau of Entomology, and the results of the work were published by the United States Department of Agriculture in 1920 in Bulletin 834, Black Grain-stem Sawfly of Europe in the United States, by A. B. Gahan. The bibliography is so extensive in this bulletin that no references will be cited in this paper.

This insect was found by the writer for the first time in Ohio near North Lima on June 26, 1934, during the course of the annual wheat field survey. A field was encountered in which a large amount of straw had fallen, which at first glance appeared to be the work of the Hessian fly. Upon closer examination, however, it was found that the main stems of the plants were neatly severed at, or slightly above, the surface of the soil. Some plants that remained standing were supported by a very thin outer portion of the straw wall and by the leaf sheath. The cut stub of the straw, as well as the end of the plant above, was tightly packed with frass. When the stub was split open, it was found to contain a fragile, thin, silken lining closely applied to the straw wall and enclosing a light lemon-yellow larva about five-sixteenths of an inch long. Specimens were sent to the Bureau of Entomology and Plant Quarantine and were identified by C. C. Hill as *Trachelus tabidus* (Fab.).

According to Gahan, "The eggs are inserted in a slit made by the female in the stem some distance above the ground." The resulting larva transverses the hollow area of the stalk and bores through the solid portion of the nodes, meanwhile feeding on the inside of the straw. The feeding is of a surface nature which does not result in seriously weakening the straw wall, thus breaking of the upper straw portions rarely if ever occurs. No instance has been observed where decomposing bacteria or fungi attended the feeding activities of the insect, inasmuch as neither the frass nor the walls of the straw were discolored.

Apparently considerable time is spent in that portion of the straw above the upper node if one may judge by the volume of castings deposited at that point. The larva retires to the base of the plant about the time the grain ripens and cuts the stem in the manner previously described. Both the stub and the end of the cut straw, as noted by Gahan, are distinctive in appearance in that they are concave or funnel shaped.

The winter is passed in the larval stage and, as may be surmised, there is but one brood each season.

An examination of 93 wheat fields and four rye fields revealed that the infestation centered in three counties adjoining Pennsylvania (Trumbull, Mahoning and Columbiana) and in two second tier counties (Carroll and Harrison). This general area is in the east-central part of the State. Light infestations were found as far west as eastern Wayne County and as far south as northern Monroe. The lightly infested territory was about twice the area of the heavily infested.

In one field in Columbiana County, 68 per cent of the straws was occupied by larvae. A considerable number of fields in the area of greatest damage was found in which 50 per cent or more of the straws was infested. However, many intermingled fields were only slightly infested.

No sawflies were found in one field of rye in the area of greatest damage, but two other fields were 7 per cent and 16 per cent infested, respectively. The insect was not found in oats, timothy, and several wild grasses. Barley was not available for examination, but according to Gahan it is recorded as a host plant in Russia.

There is some evidence to indicate that the earliest, most sturdy straws are selected by the adults for oviposition. Not only is this to be observed if one compares infested and non-infested straws from the same field, but it is more strikingly apparent if one studies two general areas in a field, one of which has been afforded an advantage of the other by reason of some stimulating influence. The better wheat invariably carries the higher population; for example, wheat protected by snow in the spring of 1934 was earlier and more vigorous than unprotected wheat. Such areas were sharply defined in some of the fields studied where snow fences erected by the State Highway Department had caused snow to accumulate and remain late in the spring. In one such field 52 per cent of the wheat in the area protected by snow was infested; whereas only 22 per cent of the adjoining unprotected area was infested.

The quality of grain produced by infested straws is surprisingly good when one considers that a larva nearly one-half inch long has grown to maturity within the straw and has severed the stem a little in advance of the normal harvest time. The post-harvest labor of collecting the fallen grain with a hay rake would have paid well in the more heavily infested fields this year.

SULPHUR FUMIGATION FOR THE CONTROL OF MUSHROOM PESTS

By A. C. DAVIS, *Assistant Entomologist*, and H. D. YOUNG, *Associate Chemist*, *Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, Washington, D. C.*[1]

During 1933 and 1934 a series of fumigations to ascertain the minimum concentrations of sulphur dioxide necessary to give a complete kill of all mushroom insects and mites exposed to it at different temperatures was conducted jointly by the Division of Truck Crop and Garden Insects of the Bureau of Entomology and the Insecticide Division, then of the Bureau of Chemistry and Soils. Fumigations were made in commercial mushroom houses in the mushroom-growing district of Pennsylvania, and in a fumigation chamber at Arlington, Va. No difficulty was experienced in obtaining, for fumigation, houses that were off bearing or empty, but few houses were available for fumigation with sulphur at the time of peak heat. Most of the growers prefer to use cyanide instead of sulphur at this time, principally because green mold frequently appears on the surface of the compost after fumigation with sulphur. Furthermore, most growers prefer not to have test insects put into newly filled houses. Fumigation of commercial houses is slow, and conditions cannot be controlled with accuracy. Therefore, to obtain data rapidly under controlled conditions and at the higher temperatures, recourse was had to the fumigation chamber.

APPARATUS AND METHODS

The fumigation chamber was a small room approximately 6 by 7 by 6½ feet, well insulated, lined with galvanized metal, and with a concrete floor. Within the chamber were steam pipes and devices for controlling the humidity and the temperature. When these various objects were taken into account, the room contained approximately 254 cubic feet of space. A 16-inch fan working on a shaft with the motor outside of the chamber gave rapid circulation of air and gases and consequently a uniform temperature in the chamber.

Changes of 10 degrees or more in temperature could be quickly made by means of the steam, either through the radiation from the hot pipes or by introducing live steam into the chamber. Once the required temperature was reached, it was maintained by means of a thermostat and a relay operating an electric heater.

In order to reproduce conditions in mushroom houses during the heating period, it was necessary to maintain the humidity as near 100 per cent as possible. A small water pipe along the walls near the ceiling of the chamber was pierced with small holes at 6-inch intervals, and sacking hung from this was kept damp by the constant drip of water from the holes. Before each test the ceiling, walls, and floor of the chamber were thoroughly wet. By introducing a little live steam occasionally

[1]Approximately equal amounts of work were done by both authors and the paper should be credited equally to each.

it was possible to maintain a relative humidity of 87 to 90 per cent or more. The humidity-control apparatus was used only as an accessory.

After some experimentation it was decided that sulphur dioxide gas from cylinders of the liquid was most satisfactory for use in the chamber, as sulphur burned within the chamber produces fog, obscuring the vision, burns too rapidly in small quantities, and the operation is difficult to control exactly. The sulphur dioxide gas passed from the cylinder through a flowmeter into the chamber. A large bottle was set into the line to reduce the pulsation in the flowmeter caused by condensation of water in the tubing. In the winter months it was necessary to place the cylinder in a pan of warm water in order to generate the gas as fast as needed.

The concentration of gas was determined by the Shelby method, in which air and gas from the chamber were aspirated through 0.01 normal iodine solution by means of a siphon. By checking the concentrations found against the amount of gas entering the chamber per minute as recorded upon the flowmeter, concentration curves duplicating those obtained in the mushroom houses during actual fumigation could be secured, and the effect of these concentrations upon insects was noted.

The insects used in the tests were the springtail *Lepidocyrtus lanuginosus* (Gmel.), adults and larvae, and all stages of the mushroom fly *Sciara* sp. and the mites, *Tyroglyphus lintneri* Osb. and *Histiostoma* sp. These are easily reared in large numbers and are representative of the insect and mite populations of the mushroom houses.

The insects, upon finely divided mushroom spawn, were placed in metal boxes having tops and bottoms of fine wire screen. As figures on percentage mortality were not desired, only approximate counts of the insects used were made. In each box there were 15 to 20 *Lepidocyrtus lanuginosus*, 10 to 20 *Sciara* larvae, several *Sciara* pupae, 10 to 50 *Sciara* eggs, 25 or 30 each of adults and larvae of *Tyroglyphus lintneri* and *Histiostoma* sp., and several thousand hypopi of each of these two species. The boxes were then placed in the chamber upon a support about 3 feet from the floor in such a way that the gas could circulate freely through them. The insects were removed when the concentration of gas had dropped below 2 mg. per liter.

Since 100°F. is the temperature along the floor of most houses during the heat, and 120°F. is the average temperature for the top of the house at that time, the fumigations were conducted at these temperatures. Two heating procedures were tried. A 4-hour rise from 75°F. and an exposure to 100°F. for 6 or 7 hours did not give an appreciably greater mortality, whether followed by fumigation or not, than a 1½- or 2-hour rise and a 20-minute exposure; so the latter procedure was used in most of the tests. At 120°F. only the mites survived the rapid rise in temperature and the 20-minute exposure, and many of these also survived the 4-hour rise and the 6–7 hour exposure.

Test fumigations were run in the chamber at 100°F. and at 120°F., with gas concentrations beginning at 2 mg. per liter and increasing as nearly as possible 0.5 mg. per liter with each test until a concentration was reached at which no insects survived. The approximate lethal

point having been thus found, tests were made at several concentrations immediately above and below that point, to determine it more closely. The concentration curve for each test was drawn separately. In each series of tests the concentrations at intervals of 5 minutes were averaged, and an "average curve" for the series was drawn from these figures. Mean concentrations were obtained by dividing the units of area within the curves as determined with the planimeter by the number of similar units in the base. Since the insects were removed when the concentration had dropped below 2 mg. per liter, the area of the curves is figured only to the point at which the concentration dropped to 1.5 mg. per liter. Those fumigations were designated as "sublethal" in which approximately 1 per cent or fewer of the insects or mites survived. "Lethal" fumigations were those in the same group or the next higher in concentration in which no insects survived.

Results

Experiments in the Fumigation Chamber.—The curves representing the average concentrations of the sulphur dioxide gas in the fumigation chamber at 100°F. and at 120°F, are given in Figure 72. It will be seen that these concentration curves approximate closely in shape that obtained in fumigating mushroom houses at peak heat (Fig. 73, C).

In fumigations at 120°F. and a relative humidity of 90 per cent or more in which the gas had a peak concentration of 5.5 mg. and a mean of 3.83 mg. per liter, and required 65 minutes to drop to 1.5 mg. per liter, some mites survived. A fumigation in which the gas had a peak concentration of about 6 mg. per liter and a mean of around 3.80 mg. per liter, and required about 65 minutes to drop to 1.5 mg. per liter, seemed to be close to lethal. Increased time of exposure permitted a slightly lower peak concentration. Figure 72,C, shows the average curve obtained for all lethal fumigations at this temperature, including one in which one mite hypopus survived. In this case the peak concentration was 5.46 and the mean 3.63, but 83 minutes was required for the concentration to drop to 1.5 mg. per liter. A fumigation in which the gas had a peak of 6 mg. per liter or more and a mean concentration of 3.80 to 3.90 mg. per liter, and required at least 80 to 90 minutes to drop to 1.5 mg. per liter, should give 100 per cent kill of all insects and mites.

In fumigations at 100°F. in which the gas had a peak concentration above 10 mg. and a mean of 6.11 mg. per liter, and required 95 minutes to drop to 1.5 mg. per liter, some mites survived. A few hypopi (less than 0.02 per cent) were able to survive a fumigation with a peak of 12.2 and a mean of 7.52 mg. per liter, which required 80 minutes to drop to 2 mg. per liter. Another fumigation with a peak of 14.7 and a mean of 7.22, requiring 92 minutes to drop to 2 mg. per liter, gave about the same rate of survival. In these cases the higher peak seems not to compensate for the short exposure.

Figure 1,A, shows an average curve of the lethal fumigations, and figure 1,B, of those in which there were a few survivals. The longer exposure, and hence the greater mean concentration, seems to account for the difference in kill, as the maximum concentrations were nearly the same.

It seems safe to say that at 100°F. a gas concentration having a peak of 12 and a mean of 8 mg. per liter or more, and requiring 110 minutes or more to drop below 1.5 mg. per liter, will give 100 per cent kill of all insects and mites exposed.

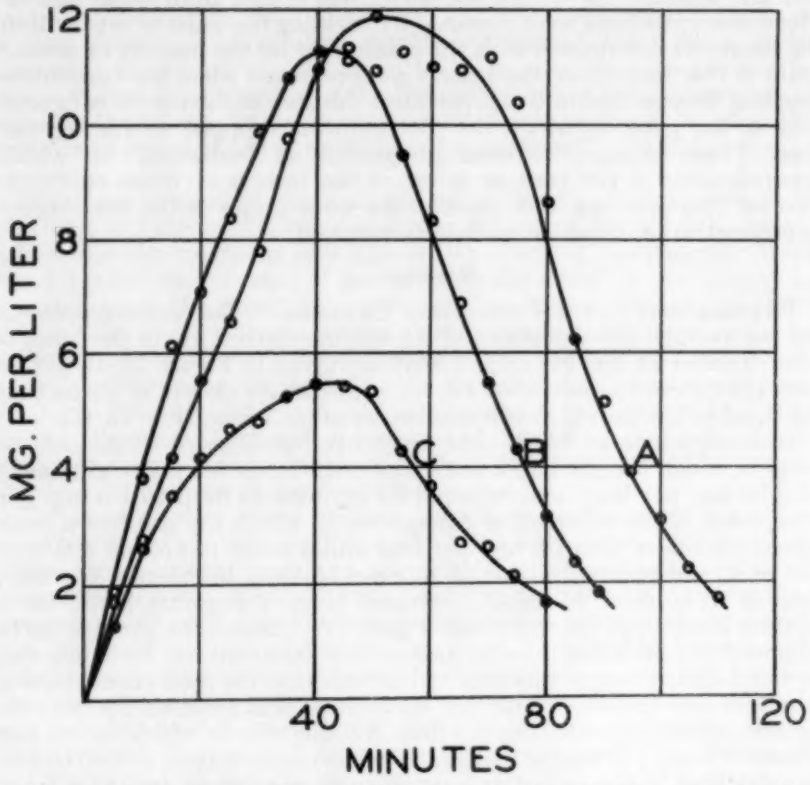

FIG. 72.—Average, curves for concentrations of sulphur dioxide gas obtained in the fumigation chamber: *A*, Fumigations giving 100 per cent kill (lethal) at 100°F., mean concentration 7.17 mg. per liter; *B*, fumigations in which a few mites survived (sublethal) at 100°F., mean concentration 6.73 mg. per liter; *C*, lethal fumigations at 120°F., mean concentration 3.63 mg. per liter.

EXPERIMENTS IN MUSHROOM HOUSES.—In the mushroom houses after the summer cleaning out, at a temperature of 70° to 80°F. and around 80–90 per cent relative humidity, a complete kill of all insects and mites exposed was obtained when the mean concentration remained above 3.97 mg. per liter for 90 minutes. For the empty houses the mean concentration for an average of all the lethal fumigations was 4.78 mg. per liter (Fig. 73,A). Figure 73,B, shows the average of all fumigations that were slightly sublethal. In this case also, both maximum and mean concentrations being nearly the same, the longer exposure accounts for

the greater kill. A fumigation with a maximum gas concentration of 10 and a mean of 5 or more mg. per liter, and requiring 200 minutes or more to drop below 1.5 mg. per liter, should give 100 per cent kill of all insects and mites exposed in empty or off-bearing mushroom houses. This concentration is easily obtained with an outside sulphur burner, using 2 pounds of flowers of sulphur per 1,000 feet of space. This concentration can also be obtained by burning flowers of sulphur in pans within the house at the rate of about 6 pounds per 1,000 cubic feet of space, but this method is slower, more difficult, and uncertain.

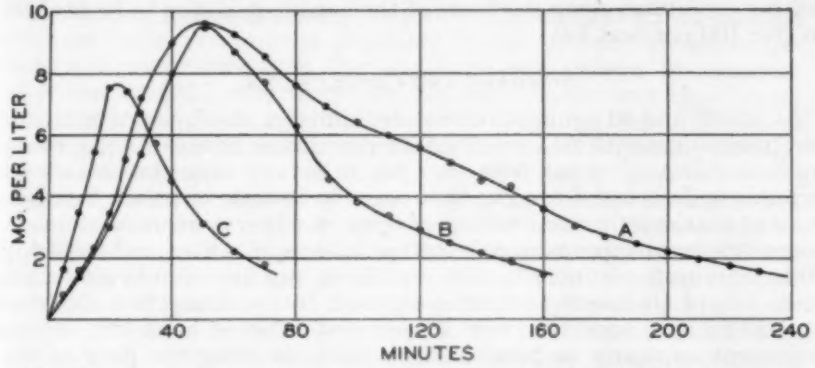

FIG. 73.—Average curves for concentrations of sulphur dioxide obtained in mushroom houses: *A*, Fumigations giving 100 per cent kill (lethal) in empty mushroom houses, mean concentration 4.78 mg. per liter; *B*, fumigations in which a few mites survived (sublethal) in empty mushroom houses, mean concentration 4.62 mg. per liter; *C*, fumigations in mushroom houses at peak heat, mean concentration 4.00 mg. per liter.

The outside sulphur burner consists of a rectangular box of galvanized metal on an angle-iron frame. The ends of the box are drawn to cones. Within the box are trays to hold the burning sulphur, and a centrifugal fan forces the fumes into the house, at the same time supplying fresh air to prevent smothering of the flame. Besides giving much more rapid generation and higher concentrations of gas with less material, and minimizing the fire hazard, the blast from the burner prevents the hot gas from rising to the top of the house and remaining there, and thus partially takes the place of fans within the house, which must be removed during sulphur fumigation.

In fumigating with sulphur while the mushroom houses are at peak heat, the greatest difficulty has been to get a gas concentration sufficiently high to be effective with the maximum dosage allowed. At this time the temperature of the top beds ranges from 125° to 150°F., that of the bottom beds from 120° to 130°F., and that at the floor from 100° to 108°F. Approximately 90 per cent relative humidity is usual, and the compost in the beds is fairly moist. Leakage and absorption bring the concentration down rapidly, and more than 2 pounds of sulphur per 1,000 cubic feet of air space increases the acidity of the bed surface too

much. Figure 73,C, shows the average curve of all fumigations made in houses at peak heat with the sulphur burner. Some of these houses could not be tightly sealed, but in tightly sealed houses concentrations as high as 11 mg. per liter have been obtained with 1½ pounds of sulphur per 1,000 cubic feet, with mean concentrations correspondingly high. In the average curve the peak is 7.66, the mean concentration 4.00 mg. per liter, and the concentration drops to 1.5 mg. per liter in 74 minutes. Comparison of this curve with that of Figure 72,C, shows both the mean and the maximum concentrations to be greater, but the curve drops to 1.5 mg. per liter in 9 minutes less. As compared with Figure 72,A, representing conditions along the floors of the houses, it is seen to be too low to give 100 per cent kill.

Summary and Conclusions

At 120°F. and 90 per cent relative humidity in the fumigation chamber, fumigations with maximum gas concentrations of about 6 mg. mean concentrations of about 3.80 mg. per liter, and requiring about 65 minutes to drop to 1.5 mg. per liter, seem to be close to lethal. Fumigations at maximum concentrations of 6 mg. per liter or more, with mean concentrations of approximately 3.80 or 3.90 mg. per liter, and requiring 80 to 90 minutes or more to drop to 1.5 mg. per liter should give complete kills of all insects and mites exposed. In the fumigation chamber at 100°F. and approximately 90 per cent relative humidity, which represents as nearly as possible the conditions along the floor of the average mushroom house during the peak heat, maximum concentrations of 14.7 and 10 mg. means of 7.22 and 6.11 mg. per liter, and requiring 92 and 95 minutes, respectively, to drop to 1.5 mg. per liter, gave less than 0.02 per cent of survival. At this temperature a concentration having a maximum of 12 and a mean of 8 mg. or more per liter, and requiring 110 minutes or more to drop to 1.5 mg. per liter, should give complete kill of all insects and mites exposed.

In mushroom houses that are empty or off-bearing, at a temperature of 70° to 80°F. and 80 to 90 per cent relative humidity, fumigations reaching a maximum gas concentration of 10 mg. or more per liter, with a mean concentration of 5 mg. or more and requiring 200 minutes to drop to 1.5 mg. per liter should give complete kill of all insects and mites exposed to the gas. These concentrations are easily reached with the use of the outside sulphur burner, burning flowers of sulphur at the rate of 2 pounds per 1,000 cubic feet of air space.

In mushroom houses at peak heat it is difficult, if not impossible, to get a concentration sufficiently high to be of great value by burning sulphur within the house at the allowed dosage of 2 pounds per 1,000 cubic feet of air space. This is true to a lesser extent even with the outside sulphur burner. The concentrations necessary for complete control along the cooler floor are the ones to be taken into consideration, since these are greater than those necessary at the higher temperatures found in the upper part of the house. Comparison of concentrations necessary for 100 per cent kill at 100°F. in the fumigation chamber with those obtained in mushroom houses at peak heat show that the latter

are too low to give a complete kill along the floor level. However, with fumigation at sufficiently high concentration, the rate of survival of insect and mite pests will be rather low.

FACTORS RELATING TO THE CONTROL OF THE MUSHROOM MITE, *HISTIOSTOMA GRACILIPES* BANKS[1]

By C. C. COMPTON, *State Natural History Survey Division, Urbana, Ill.*

Observations in Illinois during the past five years have shown that the mushroom mite, *Histiostoma gracilipes* Banks is more generally destructive to mushrooms than *Tyroglyphus lintneri* Osborn or *Linapodes antennaepes* Banks. Losses in excess of $25,000 annually were experienced over a three-year period by one Illinois mushroom grower. *Histiostoma gracilipes* Banks is most destructive to the spawn as it is running through the beds although it feeds on all stages of the developing caps.

Cultural methods play an important part in the development of a mite infestation. In order to clarify this relationahip it is necessary to give a brief summary of the important steps in mushroom culture. Fresh horse manure is thrown up in a flat pile about three feet deep and any convenient width and length, where it goes through a composting process. The pile may be constructed outdoors or in semi-open sheds. In either case all sorts of animal life which commonly breed in decaying manure have easy access to the pile. The compost pile is left undisturbed for several weeks during which time it heats. It is then turned completely throwing the outside of the pile toward the center. In this way a high percentage of the animal life in the pile is killed by mechanical means or subsequent heating. The process of heating and turning is repeated three or four times at intervals of about two weeks.

After the compositing process the manure is taken into the mushroom house and placed in the beds. The house is then tightly closed and the compost undergoes a final heating in the beds. The temperature of the beds reaches 130°F. or higher within a few days time. Mushroom growers usually ventilate the house rather than allow the temperature to go much above this point. This final heating drives the insects and mites out of the beds or kills the quiescent stages. Where the bottom beds are constructed on the floor, the temperature does not become sufficiently high to rid them of insects and the upper beds may become infested from this source. The bottom beds should be raised at least six inches off the floor with an air space beneath. The temperature of the floor rarely exceeds 100°F., and, of course, this is not sufficiently high to kill insects. As the beds heat, dipterous larvae, springtails, staphylinids, other insects and mites are driven from the beds and fall, or otherwise make their way, to the floor. Here they accumulate in enormous numbers. By using fans to circulate the air the floor temperature can sometimes be raised sufficiently to kill the animal life thereon. Much

[1]Contribution from the Illinois State Natural History Survey Project No. 8.8. (Contribution No. 3).

depends on the type of flooring, but even under the best conditions considerable survival may occur. This final heating is of vital importance in the control of mites and insects. However, the handling of the house after the heating process determines to a large extent the amount of damage that will occur from mites and insects.

After the heating process the house is ventilated and the beds allowed to cool down. When the temperature of the beds has dropped to 75°F. the spawn is planted. The house is then held at a temperature of 60°–70°F. for three to five weeks or until the spawn has run throughout the compost and the casing soil is applied. The temperature is lowered to 55°–60°F. and in another two or three weeks the beds are watered. In a short time the fruiting bodies appear.

The mite, *Histiostoma gracilipes* Banks, has a life history typical of the *Tyroglyplidae*. The occurrence of the hypopial nymphs is common and were it not for the hypopus stage in the life cycle, this mite would rarely if ever cause commercial damage to mushrooms. The mite in the hypopus stage is not capable of feeding. It is the one stage in the life cycle that will withstand drying for any length of time. The mite emerges from this stage within 24 hours in the presence of free water and temperatures of 75°–90°F. It remains in the hypopus stage only so long as it is surrounded by conditions unfavorable for its development. Hypopi in mushroom houses at the time the beds are heating and sweating always emerge from this stage and become active feeding adults in a day or so. It is impossible for this mite to stay in the hypopus stage much in excess of 24 hours under the temperature and moisture conditions existing at this time. It is recognized that the hypopial nymphs are more resistant to fumigants than the other stages, but since the hypopi have become active last stage mites before peak heat is reached, the fumigation at this time need not be stronger than sufficient to kill the feeding stages. The feeding and quiescent stages of the mite require about one-half the concentration of HCN as the hypopus stage for a complete kill.

As is common with all hypopi, the ventral surface of the body is provided with suckers by which it can attach itself to the smooth surfaces of the hairs and appendages of insects. In this way insects are largely responsible for the spread of this mite. This species is a sluggish, moisture-loving creature that cannot thrive under dry conditions. For this reason it is most destructive during the first few weeks following spawning of the beds. During this time the moisture and temperature conditions are ideal for the development of the mite which, when present, increases enormously. A single female under ideal conditions may easily be the progenitor of 8,000,000 mites within a month's time. After the beds are cased and there is less moisture in the beds the feeding stages of the mite disappear almost entirely. It is at this time that countless numbers of hypopi appear on the surface of the casing soil.

All the active stages of the mite with the exception of the hypopus injure the spawn by feeding on and cutting off the strands of mycelium as they develop from the piece of planted spawn. They may entirely destroy the spawn or check its growth until the condition of the compost is past the stage suitable for spawn growth. This species of mite also

feeds on the fruiting caps. This latter type of injury, however, is more characteristic of *Tyroglyphus lintneri* Osborn.

With this picture in mind the methods of control are clear. It is important that the empty house be free from mites before the beds are filled with new compost. The general practise of burning sulphur in the house while it is empty is effective in killing most of the pests in a house that has been thoroughly cleaned. Two to three pounds of sulphur are burned for each 1,000 cubic feet of space in the house.

It is highly desirable to compost the manure to be used at least half a mile from the house. It is extremely important to remove the old compost at least a mile from the house and a like distance from new compost piles. The new compost pile may contain mites in any of its stages. The old compost is almost sure to contain mites in varying numbers. It does not seem practicable to attempt to control mites in the compost pile before it is removed to the house. As stated above, the insects and mites are driven from the beds at the time of the final heating. Fumigation with cyanide at this time kills all mites not on the floor. Sodium cyanide at 5 ounces per 1,000 cubic feet or Cyanogas 10 ounces to 1,000 cubic feet has been found effective at a 24 hour exposure. In order to kill the insects and mites on the floor, water at a temperature of 180°F. at the boiler, is run onto the floor with a hose immediately following fumigation, i. e., as soon as the house has been aired. In place of hot water a miscible oil-lye spray has been applied to the floor with excellent results. Such a spray is prepared by adding 2½ gallons of miscible oil and 1 pound of lye to 50 gallons of water. The floor must be thoroly wet with this solution.

The next step is to prevent reinfestation from outside. The house is opened for airing and cooling following the fumigation at peak heat. At this time the warm, moist compost in the beds is very attractive to the various Diptera and Staphylinidae which breed in or frequent fermenting manure. Insects carrying hypopi may come from adjacent houses under production at the time, from old or new compost piles or from almost any source of decaying organic matter. When such insects alight on the beds the hypopi become detached and enter the compost to breed. Such small flies as *Sciara* sp. have been observed to carry as many as fifty hypopi each. Therefore the problem is to prevent the flies and other insects from entering the house. This has been accomplished by screening windows, doors and ventilators with 20 mesh copper screening. Mushroom growers sometimes object to the use of fine screen because it interferes with ventilation but where mites are a serious problem screening pays big dividends. As an aid to ventilation, fans have been used with success.

Mushroom growers often make the mistake of allowing flies to enter the houses after heating and then fumigating to control the flies. Frequent fumigation will hold the flies in check but has little effect on the mites. Flies carrying hypopi are overcome by the fumigant and drop to the beds where the concentration of gas is not high enough to kill the hypopi.

Other rather frequent carriers of mite hypopi are the laborers working around the house. Where a part of the plant is in production while the other houses are being started, it is a common practise for the men to pick mushrooms in the morning and spawn the beds in the new house in the afternoon. In this way large numbers of hypopi are taken into the new beds on the clothing. This danger has been eliminated by having the men make a complete change of clothing before entering the newly filled house. The change of clothing not in use is kept in a tight chest supplied with paradichlorobenzene. A liberal sprinkling of paradichlorobenzene crystals through the clothing will kill the hypopi.

The mite, *Histiostoma gracilipes* Banks, is most likely to be troublesome on the summer or fall crops. Beds filled during freezing weather are not likely to become infested from outside sources because of the inactivity of flies and other insects.

THE RELATION OF ENTOMOLOGISTS TO THE EXTERMINATING BUSINESS

By GEORGE L. HOCKENYOS, *Springfield, Ill.*

Some of the exterminating companies now operating were already old and established concerns when the American Association of Economic entomologists was organized in 1889. In their parallel development there has been a marked contrast between the development on one hand of the business of exterminating and the development of insect control methods by professional entomologists on the other. The professional entomologist in addition to being a technically trained man has considered it at once a privilege and a duty to report his findings to his professional associates. The exterminators, however, have been at best good ethical business men and at worst irresponsible itinerants to whom the popular term "Rat Catcher" has been applied. Even among the best and most responsible exterminating companies there has been a large measure of secrecy maintained regarding their methods of exterminating and it is doubtless because of this secrecy and also the lack of technically trained men in the exterminating industry that has resulted in so little real advance in exterminating methods being made by the exterminators themselves. The advances that have been made can be traced largely to the efforts of professional entomologists either in the public service or in the service of the insecticide manufacturers. It is regrettable that there has been so little contact between the professional entomologists interested in insect control and the man engaged in exterminating business as the commercial exterminator has a far better opportunity than does the professional entomologist for making practical tests of new materials and methods. I believe I am safe in saying that some of the methods described in state bulletins on the control of household insects have been found by exterminators to be entirely unsatisfactory and, conversely, that some of the most universally successful methods of exterminators are not mentioned by these same bulletins.

In the last two years there have been developments which seem destined to bring about an entirely new relationship between the entomological profession and the exterminating business. Legislation has been the chief cause for this change. The national recovery act made necessary a trade association among the exterminators in order that a code might be formulated. Accordingly, in the summer of 1933 not one but two national exterminator's associations were formed. These were soon blended into The National Association of Exterminators and Fumigators. This is now a live and growing organization of approximately two hundred members with the Exterminators' Log as their official magazine. In December of 1932 there was also organized the Society of Industrial and Consulting Entomologists, which limits its membership to the professional entomologists who are not in the public service. It includes therefore, technically trained entomologists associated with exterminating, insecticide manufacture, or acting as consultants. In some of the larger cities there have recently been organized successful associations of the local exterminators, in New York City this group numbers about two hundred forty.

Owing to a number of deaths resulting from fumigating accidents several of the larger cities have adopted ordinances licensing and regulating those engaged in fumigation and in some cases the business of exterminating. The requirements of these ordinances can be met by men who are not technically trained entomologists. Recently, however, the state of Louisiana has passed a law requiring that all exterminating and fumigating companies operating in that state be in charge of licensed men and the examination required to obtain a license is such that only technically trained entomologists can pass it. It seems quite probable that similar legislation will be introduced in other states and if the present tendency for the control of the commercial exterminating operations by municipal and state legislation continues, the time may not be far distant when technical training will be just as much a requirement of the practising exterminator as it now is of the practising pharmacist and the relation between the graduate entomologist and the exterminating business may be much the same as that between the graduate pharmacist and the drug business.

There are about seven hundred exterminating companies in the United States and if development proceeds as I have indicated above there will be a large new field open to university graduates in Entomology.

A NEW SPREADER FOR NICOTINE[1]

By C. O. EDDY, *Kentucky Agricultural Experiment Station*

This is a report of a liquid spreader for nicotine that contains about twice the amount of active ingredients and is four times as effective as the commercial liquid potassium soap spreaders in the control of *Aphis*

[1]The investigation reported in this paper is in connection with a project of the Kentucky Agricultural Experiment Station and is published by permission of the Director.

rumicis Linn., on nasturtium leaves. Liquid potassium soap spreaders such as potassium oleate, liquid tar soap, and cocoanut oil soap contain 40 per cent active ingredients and 60 per cent water. Four parts of these liquid soap spreaders are required to spread 1000 parts of a nicotine and water solution on aphids on nasturtium leaves. One part of the new spreader with each 1000 parts of nicotine and water spread equally as well.

During the past two years, while the new spreader was in practical field use, it has been called "Spreader 385" because it bore that number in the laboratory and also "Taroleate Spreader" because its principal ingredients are pine tar oil and oleic acid.

In a previous report,[2] it was stated that certain pine tar oil fractions used with liquid soap increased the efficacy of aphid control. Certain fractions of pine tar oil are more toxic to aphids than others, and certain fractions increase the efficacy of the combination to spread and to wet both aphids and plant surfaces. Some fractions of tar oil are very expensive, others relatively cheap. As to both efficacy and reasonableness of cost, Southern commercial destructively distilled pine tar oil of specific gravity 1.035 is best adapted for use with liquid soap.

By a previous experiment it was found also that tar-oil-liquid soap combinations are more effective when the tar oil is added without alkali to provide for its saponification or neutralization.

In later experiments it was found that relatively large amounts of tar oil could be added to soap and water and that the solution would spread and wet leaf surfaces more effectively and at lower dilutions. Since tar oil increased the spreading and wetting, and since the liquid potassium soap spreaders contained 60 per cent water, experiments were begun in the use of tar oil in place of water in making the spreader.

The experiments in the use of tar oil in place of water in making spreaders failed at first because the finished product was solid and not readily soluble in water. It was found, however, that by using a solvent such as alcohol, acetone, ether, and diacetone in the combination, that pine tar oil could be used in place of small portions of the water. When a combination of solvents was used, more tar oil could be used than with a single solvent. Thus a combination of alcohol, ether, acetone, and glycerine was more effective than any one or two or three of these solvents.

Because the combined solvents increased the amount of tar oil that could be used with the spreader, many complex solvents were obtained for trial.

Ethylene glycol mono-ethyl ether was thus found to be a good compound for use as the solvent in the spreader. Several related compounds were nearly as effective. In some combinations, ethylene glycol monobutyl ether was equally as good but in general the ethylene glycol mono-ethyl was found to be the best solvent to use. When 10 per cent of ethylene glycol mono-ethyl ether was used in the formula, 45 per cent of tar oil could be incorporated in the new spreader.

[2]Eddy, C. O. Role of Some Southern Pine Products in the Control of *Aphis rumicis* Linn., Journal of Economic Entomology, Vol. 27, No. 2, April, 1934.

In making the new spreader, the same oils were used as in the manufacture of commercial liquid soap spreaders. These oils are cocoanut oil and oleic acid. Cocoanut oil-tar oil combination diluted with water could not be used because a heavy flocculate formed. The oleic acid-tar oil combination mixed with water easily. No flocculate formed.

The formula for the tar oil-oleic acid combination is as follows:

SPREADER 385

Formula 1

5.00%	water
7.40%	potassium hydroxide (92% flakes)
44.30%	pine tar oil (sp. gr. 1.035)
10.00%	ethylene glycol mono-ethyl ether
33.30%	oleic acid
100.00	

The ingredients are to be added in the order given from top to bottom. The potassium hydroxide is dissolved in the water before the pine tar oil is added. This combination requires no heat. In the experiment, when the water was reduced to three per cent, the water dissolved only a portion of the potassium hydroxide. It was necessary, therefore, to apply heat at 140°C. after adding the pine tar oil but before adding the solvent and oleic acid.

During the past year, a second formula has been used that permits an increase of pine tar oil and a decrease in solvents in the formula. Formula 2 has about the same effect as Formula 1. It is a cheaper spreader, mixes more readily with water, but is more complex. Each formula thus has advantages.

SPREADER 385

Formula 2

5.00%	water
7.40%	potassium hydroxide (92% flakes)
48.80%	pine tar oil (sp. gr. 1.035)
3.00%	iso amyl alcohol
1.00%	phenol (85%)
1.50%	ethylene glycol mono-ethyl ether
33.30%	oleic acid
100.00	

The same mixing directions given for Formula 1 apply to Formula 2. It was necessary to change the proportions of the solvents with different samples of tar oil and oleic acid.

A small amount of a fine dark precipitate resulted in the spreader when both Formula 1 and Formula 2 were used. The precipitate was filtered out in part of the testing work. No change in results was noted. Filtering was more effective when the temperature of the spreader was lowered to 40° or 50°F. The precipitate came out readily on coarse fast filters. Heat and agitation caused resolution of the precipitate.

The precipitate was reduced when materials such as creosote acids, pine tar acids, xylene, sulfonated castor oil, and glycerine were used. It was prevented when resin was substituted for a small but equal por-

tion of both pine tar oil and oleic acid. In field tests about 20 to 25 per cent of resin was used in the spreader.

The toxicity of nicotine to aphids was greater with Spreader 385 than with tar oil rendered water soluble by the use of potassium hydroxide or with soluble tar oil containing 10 per cent potassium oleate.

The dilution of one part in 1000 parts, the effective dilution for Spreader 385, is equivalent to one pound, or approximately one pint, to 125 gallons. At a rate varying from one to two pints per 100 gallons, Spreader 385 has been in use for two years in field tests in the control of aphids, leafhoppers, and thrips, on peaches, apples, grapes, and vegetable crops. From these experiments, it seems that a minimum dosage of one pint per 100 gallons is adequate for surfaces like nasturtium leaves infested with aphids. Porportionately larger dosages are required for surfaces that are more difficult to wet, just as with soap spreaders.

The cost of the tar oil and solvents in Spreader 385 (taroleate spreader) is less than for the ingredients used in liquid potassium soap spreaders. Since the effectiveness is approximately four times greater than the liquid soap spreaders, there is a saving of approximately 50 per cent.

AN OUTBREAK OF THE SCREW WORM, *COCHLIOMYIA AMERICANA* CUSHING AND PATTON, IN NORTHWESTERN IOWA[1]

By E. F. KNIPLING, *Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture*, and H. D. TATE, *Entomology and Economic Zoology Section, Iowa State College, Ames, Iowa*[2]

A number of dipterous larvae were collected by W. A. Aitken, D. V. M., in September 1934, in the vicinity of Merrill, Plymouth County, Iowa, from wounds of domestic animals. These larvae were determined as the screw worm, *Cochliomyia americana*, recently described by Cushing and Patton.[3] Apparently this is the first authentic record of the occurrence in Iowa of this species, which is one of the major livestock pests of the southern part of the United States. To the writers' knowledge this species has not previously been reported from latitudes as far north as this.

A letter by the collector (W. A. Aitken) accompanying the specimens stated that many cases of myiasis in livestock were being encountered in the vicinity of Merrill, Iowa. Because of the possibility of its becoming a serious pest in a heretofore uninfested territory it seemed advisable to determine the abundance and distribution of *C. americana* in Iowa.

[1]Journal Paper No. J-233 of the Iowa Agricultural Experiment Station, Ames, Iowa, Project No. 372. In cooperation with the Division of Insects Affecting Man and Animals, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.

[2]The writers are greatly indebted to the veterinarians of western and northwestern Iowa, and especially to Dr. W. A. Aitken, for aid in obtaining this information.

[3]Cushing, Emory C., and Patton, W. S. *Cochliomyia americana* sp. nov., The Screw-worm Fly of the New World. Annals of Tropical Medicine and Parasitology, Vol. 27, No. 4, pp. 539–551, illus. 1933.

As the best method of obtaining this information appeared to be through contacts with veterinary practitioners, a questionnaire concerning maggot infestations in domesticated animals was presented to a number of veterinarians in the western and northwestern parts of Iowa, and information concerning this problem was obtained from a number of points in that part of Iowa and from two points in South Dakota near the Iowa State line.

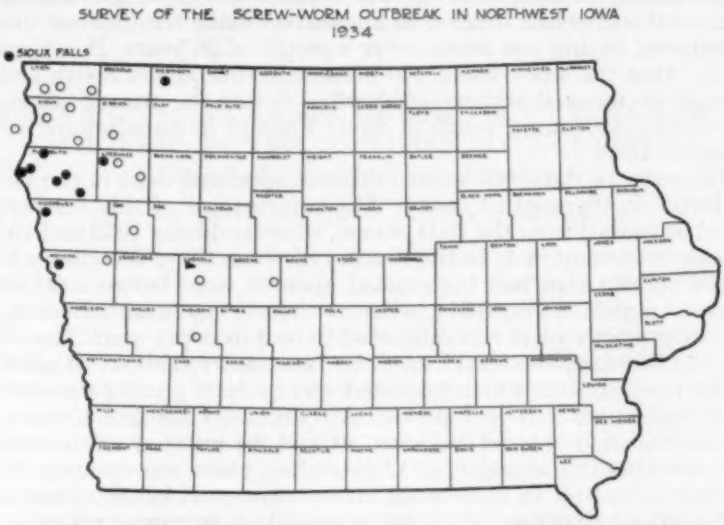

FIG. 74.— ● Localities reporting a marked increase in number of cases of myiasis in domestic animals during 1934; ●, localities reporting cases in former years, but no increase in 1934. Sioux Falls and the locality just west of Sioux County, Iowa, are in South Dakota.

As a criterion for determining whether or not screw worms occurred in any specific localities it was assumed that *C. americana* was present in areas in which the number of cases of myiasis reported by veterinarians during the 1934 season was markedly greater than in any previous year. It is not likely that all of the infestations reported were caused by *C. americana*, since other species of blowflies are known to infest occasionally the wounds of domestic animals in Iowa. The probability however, that this species was largely responsible for the increase is indicated by the fact that specimens of *C. americana* have been obtained from eight infested animals from Plymouth and Woodbury Counties, Iowa, although *Phormia regina* was also found in the wound of one of these animals.

The localities in which the number of cases of myiasis encountered by the veterinarians was greater during 1934 than in previous years are indicated by black dots on the map (Fig. 74), while the places in which cases have occurred in former years but in which no increase was noted by veterinarians in 1934 are indicated by ○. On the basis of this survey

it appears that the outbreak occurred principally in Plymouth County and extended into Woodbury and parts of Monona and Cherokee Counties. It is possible that *C. americana* was present also in the vicinity of Lake Park, Dickinson County, although in this locality the increase in number of cases over previous years was not great and may have been due to unusual activity of other species of blowflies such as *Phormia regina* and *Lucilia sericata*. In the vicinity of Sioux Falls, South Dakota, an increase in the number of cases of myiasis was reported. The veterinarian in this area had treated 20 infested animals, the greatest number encountered in any one season over a period of 26 years. It is therefore possible that the screw worm was present in this part of South Dakota, although no unusual activity of blowflies during the present season was reported in the county south of Sioux Falls or in an adjoining county (Lyon) in Iowa.

The center of the screw worm outbreak appeared to be in the vicinity of Merrill in Plymouth County. The veterinarian of this territory reported 94 cases during the 1934 season, whereas during 1932 and 1933 no cases were encountered. In the vicinity of Sioux City, Woodbury County, the veterinarian had been called upon to treat between 30 and 40 infested animals during 1934, whereas the average number treated for the four previous years was estimated to be 2 to 3 per year. The veterinarian at Whiting, Monona County, had encountered about 30 cases during the present year, which he stated was by far a greater number than the average over a 9-year period. At Marcus, Cherokee County, the veterinarian had treated between 40 and 50 infested animals during 1934, whereas the average for 12 preceding years was estimated to be between 12 and 15. In each of the above-mentioned localities the veterinarians stated that practically every wound on an animal resulted in an infestation of maggots. In other localities, principally in Plymouth County, the increase in number of cases during 1934 over previous years was similar to that near the points mentioned.

In all localities in which an increase in number of cases of myiasis was reported the total number of cases was 330, or an average of 30 for each locality. In 14 localities in which no increase in the number of cases was noted during 1934 the average number for each was approximately 7. In each place from which information was obtained the cases reported are only those actually treated by the veterinarians. No doubt many other cases were treated by the stock owners.

During 1934, the period of greatest activity of maggots in this district occurred between about the 8th of August and the middle of October. Specimens of *C. americana* were obtained from one case as late as October 21. In previous years, although the number of cases reported was small, the greatest activity in general seemed to be late in the spring and early in the summer.

In the present increased outbreak cattle, principally newborn calves, were the animals more often infested. Horses, sheep, hogs, dogs, and chickens were also infested in about the order named.

We can only speculate as to the cause of the outbreak of screw worms in this district. It is possible that infested animals shipped to the packing

plants in Sioux City, Iowa, introduced the parasite and that climatic conditions during the season of 1934 were favorable for its spread. The heavy outbreak of screw worms in the Southeastern States this year, together with the unusually large numbers of cattle being moved from drought-stricken to less seriously affected areas, may also have been an important factor in the introduction of this pest into new territory. A less plausible explanation, in the authors' estimation, is that the flies migrated into this region and found the climatic conditions favorable for a rapid increase in numbers, resulting in the outbreak.

THE TOXICITY OF CARBON DIOXIDE-METHYL FORMATE MIXTURES TO THE CONFUSED FLOUR BEETLE (*TRIBOLIUM CONFUSUM* DUV.)[1]

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Various combinations of mixed gases and liquids have been used in the past for controlling insect pests in stored products. In most instances, however, the secondary chemical was incorporated in order to reduce the inflammability of the principal killing agent. At the present time carbon tetrachloride is frequently added to carbon disulphide, ethylene dichloride and propylene dichloride in varying proportions to give mixtures which may be used commercially without danger of fire or explosions. Chloropicrin is not inflammable, but Chapman (*6*) and Strand (*31* and *32*) have shown that mixtures containing equal parts of carbon tetrachloride and chloropicrin have higher vapor pressures than chloropicrin alone, and consequently evaporate at a faster rate. Some experiments by Mackie (*24*, *25* and *26*) and by G. W. Jones and R. E. Kennedy (*20*) show that CO_2 may be used to advantage in preventing explosions of carbon disulphide and ethylene oxide, respectively. In a recent article the writer (*21*) gives further data on reducing the limits of inflammability of certain fumigants with CO_2.

A review of the literature discloses some interesting information concerning the use of CO_2 as a fumigant for destroying insect pests in various types of stored products. Some of the earlier investigations are discussed briefly in the following paragraphs.

The use of CO_2 to accelerate the penetration of respiratory insecticides into the tracheal system of insects was apparently first advocated by Hazelhoff (*18* and *19*). This investigator suggests that the addition of small amounts of CO_2 may serve to increase the effectiveness of a given concentration of a gaseous fumigant such as hydrocyanic acid gas. Considerable experimental and practical work along this line has been conducted in the U. S. Department of Agriculture by Cotton and Young

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(*10*), Cotton (*8* and *9*) and Back, Cotton and Ellington (*2*). Shortly after Hazelhoff's first paper appeared, Brinley and Baker (*5*) reported that small amounts of methyl acetate seemed to increase the toxicity of liquid hydrocyanic acid gas, by keeping open the spiracles of the insects.

Peculiarly, however, it has recently been observed by Campbell [unpublished data, see (*9*), P. 1099] and Cotton (*9*) that the insecticidal action of hydrocyanic acid gas is not increased by the addition of CO_2, as was suggested by Hazelhoff. These results are substantiated by Pratt, et al (*30*), who observed that the addition of 1% and 10% of CO_2 actually decreased the toxicity of 0.2% HCN to the ladybird beetle (*Hippodamia convergens* Guerin). These results furnished the first indication of the possibility of such a phenomenon as "Protective Stupefaction" (*15* and *29*). On the other hand, McGovran (*27*) observed that a concentration of 15% CO_2 may increase the rate of tracheal ventilation of the grasshopper (*Arphia sulphurea* Fab.) as much as about 20 times the normal, or slightly more than 1900%. The effect of 1% CO_2 was to increase the average rate about 5%. However, no fumigants were used in admixture with the 1% and 15% CO_2-air mixtures.

Carbon dioxide has frequently been recommended for the control of various insect pests, but when used alone it has never proved entirely satisfactory. The poor results obtained from its use were, in general, attributed to its mild toxicity, whereby the insect in the absence of oxygen enters a comatose or torpid state; that is, the CO_2 appeared to act like a narcotic. This condition was observed as early as 1906 by Cole (*7*) and 1916 by Barnes and Grove (*3*). The latter workers investigated the possibility of using CO_2 to destroy wheat insects (*Sitophilus oryzae*, *Attagenus undulatus* and *Rhizopertha dominica*) in India. Newstead and Morris (*28*) state that the mite, *Tyroglyphus farinae*, remained inert in atmospheres of almost pure CO_2 for various periods of time up to 50 hours, but quickly became active when the treatment was discontinued. Harukawa (*17*) and Zacker (*33*) report that the rice borer (*Chilo simplex*) and the cigarette beetle (*Lasioderma serricorne*), respectively, are resistant to atmospheres of CO_2.

Contrary to the above statements, however, some references are found in the literature in which CO_2 is recommended as a satisfactory fumigant for grain weevils and other insects. Hargreaves (*16*) states that the gas (containing approximately 20% of CO_2) obtained by passing air over a bed of red-hot coke in a furnace is effective in killing the weevils in wheat stacks in Australia. Froggatt (*14*) recommends that infested corn be treated in iron tanks with CO_2 at the rate of 1 pound for each 12 bushels of grain. The gas should be discharged slowly from the cylinder, 1 pound in 3 minutes, over the surface of the grain. Due to its greater density, the CO_2 will diffuse downward in the column of grain. The adult weevils and larvae are killed in a period of 7 days by this treatment. According to Begemann (*4*), CO_2 is also a suitable fumigant for controlling *Stephanoderes hampei* Ferr. in coffee seed. Dendy and Elkington (*13*) give data on the toxicity of various percentages of CO_2 to the granary weevil (*Sitophilus granaria*) and the rice weevil (*S. oryzae*). The results of their observations are discussed briefly below. In other

papers (*11* and *12*), these authors also discuss at length the question of air-tight storage of grain to prevent insect depredations.

The data presented in the above publications show that, in general, CO_2 alone is not effective as a fumigant, except when used for long periods of time, or in excessively high concentrations. It is the purpose of this paper to show that CO_2 gas in practical concentrations can be made more toxic to insects by the addition of small quantities of certain other chemicals. The data presented herein should not be confused with those previously published by Hazelhoff, Cotton or Young, which show that when CO_2 is added in relatively small amounts to a fumigant the rate of respiration of the insect is increased and thereby the effectiveness of the fumigant.

As stated above, Dendy and Elkington have previously shown that high concentrations of CO_2 are toxic to grain weevils. These investigators conducted a number of experiments to determine the poisonous effect of CO_2, at the same time maintaining the percentage of oxygen as nearly normal (20.96) as possible. This involved a corresponding variation in the percentage of nitrogen in the atmospheres, but as this gas has no physiological action the variations were disregarded. Briefly, they summarize their results as follows, "The higher the initial percentage of CO_2 (up to a certain point) the more rapidly is the lethal effect produced, so that in an atmosphere containing from 78.58 per cent. to 79.38 per cent. of CO_2 all the weevils are killed in 21 hours, though 20.61 per cent. of oxygen still remains. * * *If we remember that in an initially normal atmosphere the weevils are able to use up practically the whole of the oxygen (*in an air-tight container*[2]) before succumbing, it will be evident that the result in these cases must be due to the poisonous effects of the carbon dioxide. * * *Pure (moist) carbon dioxide is less fatal in its effects than carbon dioxide with a small admixture of oxygen. * * *We would suggest that the explanation of this phenomenon is that even a small amount of oxygen serves to keep the metabolism going sufficiently to enable the carbon dioxide to exert its poisonous effect, while in the complete absence of oxygen metabolism is entirely suspended."

In the tests presented in this paper, the insects (*Tribolium confusum*) were fumigated in atmospheres containing 50, 75 and 100%[3] CO_2, and the results obtained confirm for this insect the findings of Dendy and Elkington on weevils. The investigations of Cotton and Young, therefore, show that low concentrations of CO_2 may be effectively used to increase the toxicity of various fumigants, whereas the data presented by the writer show that relatively high percentages of CO_2 have a toxic effect on insects and that this degree of toxicity may be markedly increased by the addition of certain organic chemicals.

Laboratory tests show that a perfect kill of *Tribolium confusum* is obtained in a 5 hour period with carbon disulphide at a concentration

[2]Author's italics.

[3]The CO_2 gas used in these experiments was taken from a cylinder of the commercial liquefied product. The purity at the filling stand varied from 99.20 to 99.96% (average 99.80%).

of 65 milligrams per liter. When exposed to atmospheres containing only 25 milligrams per liter, however, it has been observed that, although the beetles soon become motionless, they recover and continue to breed when removed from the fumigation flask at the end of the 5 hour exposure. On the other hand, if the beetles are placed in an atmosphere containing at least a lethal concentration of a chemical such as methyl formate, they continue to show some activity for the duration of the 5 hour exposure, and do not die until after they are removed from the flask. In non-lethal concentrations of methyl formate the insect is quite active over an extended period of time, without any apparent harmful effects. The two illustrations given above show that the confused flour beetle becomes inactive in concentrations of carbon disulphide which are non-lethal in 5 hours, recovering when removed to fresh air; whereas, in a lethal atmosphere of methyl formate, the insect remains more or less active for the duration of the exposure, but dies within the next several days. The above tests indicate that if a compound of the kind discussed above, which increases the activity of the insect, or results in increased activity, be added to atmospheres of CO_2, the mixture of gases should be highly toxic. This appears to be substantiated by the data presented in the following pages. Pratt, et al (*30*), state as follows, "In general it was found that those compounds whose vapors were effective in increasing the toxicity of HCN were either predominately toxic, or moderately toxic and irritating." Methyl formate falls into the latter class.

METHOD.—The apparatus employed for conducting the toxicity experiments presented in this paper has been recently described by the writer (*22*). Briefly, the set-up was designed to allow the vapors of the volatile fumigants, instead of the liquid compound, to be introduced into a partially evacuated 5-liter Pyrex fumigation flask, the amounts being measured by means of a mercury manometer. The fall of the mercury in the manometer is a direct measure of the concentration of the gases in the fumigation flask. This is based on the fact that the vapor of 1 mol of a compound occupies 22.4 liters at standard conditions. Fractional parts, expressed as milligrams/liter or per cent by volume, may therefore be conveniently and accurately measured. Air is then allowed to flow in until the mixture within the flask is reduced to atmospheric pressure.

Adults, larvae and eggs of the confused flour beetle, *Tribolium confusum*, were used in the tests reported in this paper. The insects were reared on coarsely cracked whole wheat at a constant temperature of 30°C. and a relative humidity of 60 to 70%. No beetles were used in the experimental work which were older than 6 to 8 weeks, although numerous checks showed that there was no natural mortality of the young adults. After treatment, the insects were placed on ground whole wheat in specimen bottles and examined each day for a period of a week or more. The criterion of death was the inability of the insect to walk on a flat surface, as experience showed that, in general, those which could not walk within two or three days after the treatment nearly always failed to recover. The eggs to be used in the tests were obtained only from

young adults. The method described by Lindgren and Shepard (*23*) was followed in caring for the treated eggs. Each fumigated lot of eggs was accompanied by several checks.

RESULTS.—The results are discussed under the following subheads; (1) toxicity of the additive compound (methyl formate), with air as the component part of the mixture, (2) the toxicity of atmospheres containing various percentages of CO_2 and (3) the toxicity of mixtures of various percentages of CO_2 to which have been added quantities of methyl formate which are non-lethal in 5 hours.

(1). TOXICITY OF METHYL FORMATE.—In Table 1 is shown the data obtained on the toxicity of this compound, in air, to adults of *Tribolium confusum*.

TABLE 1. TOXICITY OF METHYL FORMATE TO ADULTS OF *Tribolium confusum* AT 30°C. EXPOSED FOR 5 HOURS

Concentration, Mg./liter	Number of insects	Number dead	Percentage mortality
10	50	0	0
10	50	0	0
15	50	13	26
15	50	16	32
20	50	33	66
20	50	40	80
25	50	50	100
25	50	50	100

(2). TOXICITY OF CO_2.—A series of experiments was conducted to determine the toxicity of mixtures of various percentages of CO_2 to *Tribolium confusum*. The results of these tests are shown in Table 2 and Figure 75. It is interesting to note that all of the beetles are killed in a period of 10 hours with 100% CO_2, whereas 20 hours are required for a complete kill with mixtures of 75% CO_2 and 25% air and 44 hours with mixtures of equal parts of CO_2 and air.

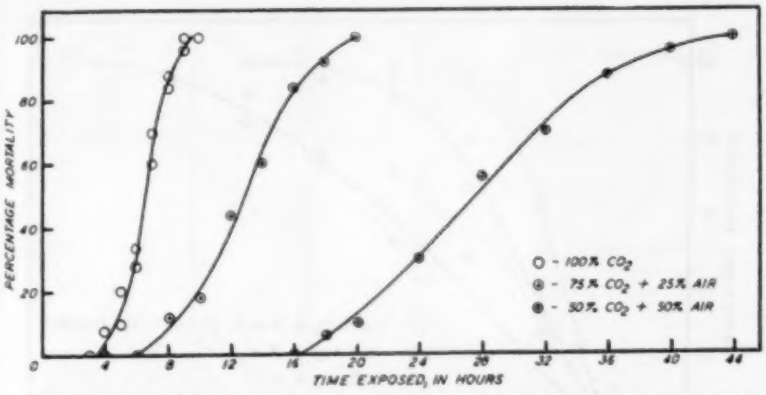

FIG. 75.—Toxicity of atmospheres of 50, 75 and 100% CO_2 to adults of *Tribolium confusum* at 30°C.

(3). TOXICITY OF MIXTURES OF CO_2 AND METHYL FORMATE.—In Table 3 and Figure 76 are shown the results obtained when methyl for-

TABLE 2. TOXICITY OF VARIOUS PERCENTAGES OF CO_2 TO ADULTS OF *Tribolium confusum* AT 30°C. FIFTY INSECTS USED IN EACH TEST

Per cent of CO_2	Hours exposed	Number dead	Percentage mortality
	3	0	0
	3	0	0
	4	0	0
	4	4	8
	5	5	10
	5	10	20
	6	14	28
	6	17	34
100	7	30	60
	7	35	70
	8	42	84
	8	44	88
	9	48	96
	9	50	100
	10	50	100
	10	50	100
	6	0	0
	8	6	12
	10	9	18
75	12	22	44
	14	30	60
	16	42	84
	18	46	92
	20	50	100
	16	0	0
	18	3	6
	20	5	10
	24	15	30
50	28	28	56
	32	35	70
	36	44	88
	40	48	96
	44	50	100

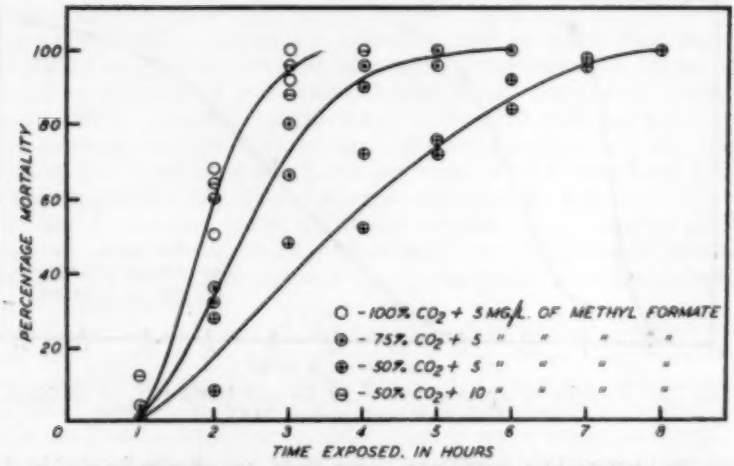

FIG. 76.—Toxicity of atmospheres of 50, 75 and 100% CO_2, plus methyl formate at the rate of five milligrams per liter, to adults of *Tribolium confusum* at 30°C.

mate is added at the rate of 5 milligrams /liter to atmospheres containing 50, 75 and 100% CO_2. Reference to Table 1 shows that this concentration of methyl formate is not toxic to the beetles in a 5 hour period.

It seemed advisable at the beginning of this phase of the investigation to add only small quantities to the CO_2-air mixtures; that is, concentrations of methyl formate which in themselves were not toxic to the insects in the standard 5 hour period of treatment. A comparison between Tables 2 and 3 brings out the following information; (1) all of the beetles are killed with 100% CO_2 plus methyl formate in 4 hours, as compared with 10 hours for 100% CO_2 alone, (2) a perfect kill in 6 hours with mixtures of 75% CO_2 and 25% air plus methyl formate, as compared with 20 hours for the 75% CO_2–25% air mixtures without the added chemical, and (3) a 100 per cent mortality in 8 hours with mixtures of 50% CO_2 and 50% air plus methyl formate, as compared with the 44 hours required for the 50% CO_2–50% air mixtures without the methyl formate. In Table 3 is also shown the results obtained when methyl formate was added to the 50% CO_2–50% air mixtures at the rate of 10 milligrams/liter. All of the insects were killed in 4 hours, as compared with 8 hours when 5 milligrams/liter were added and 44 hours when none was added. It should also be noted that a concentration of 10 milligrams/liter of methyl formate, in air, is not lethal to the beetles with an exposure of 5 hours.

TABLE 3. TOXICITY OF VARIOUS PERCENTAGES OF CO_2, PLUS SMALL QUANTITIES OF METHYL FORMATE, TO ADULTS OF *Tribolium confusum* AT 30°C. FIFTY BEETLES USED IN EACH TEST

Per cent of CO_2	Methyl formate added in following proportions— 5 Mg./liter Hours exposed	Number dead	Percentage mortality	10 Mg./liter Hours exposed	Number dead	Percentage mortality
	1	0	0			
	1	0	0			
	2	25	50			
100	2	34	68	No tests conducted		
	3	46	92			
	3	50	100			
	4	50	100			
	4	50	100			
	1	0	0			
	1	2	4			
	2	16	32			
	2	18	36			
	3	33	66			
	3	40	80			
75	4	45	90	No tests conducted		
	4	48	96			
	5	48	96			
	5	50	100			
	6	50	100			
	6	50	100			
	1	0	0	1	0	0
	1	0	0	1	6	12
	2	4	8	2	30	60
	2	14	28	2	32	64
	3	24	48	3	44	88
	3	24	48	3	48	96
	4	26	52	4	50	100
	4	36	72	4	50	100
50	5	36	72	–	—	—
	5	38	76	–	—	—
	6	42	84	–	—	—
	6	46	92	–	—	—
	7	48	96	–	—	—
	7	48	96	–	—	—
	7	49	98	–	—	—
	8	50	100	–	—	—
	8	50	100	–	—	—

A series of experiments has also been conducted with certain other compounds, in which small quantities were added to the various percentages of CO_2. Some of these other chemicals likewise increased the toxicity of CO_2, whereas others showed no apparent effect at the concentrations used. The results of these additional tests will appear at a future date.

The significant data presented in Tables 2 and 3 are summarized in Table 4. It is obvious from a glance at the table that the addition of methyl formate aids materially in reducing the time required for the various percentages of CO_2 to affect a 100% mortality of the beetles. The approximate 50% mortalities are also included in the table. It should be noted that these 50% points are in about the same ratio as the corresponding 100% mortalities.

TABLE 4. HOURS REQUIRED TO OBTAIN 50 AND 100% MORTALITY OF *Tribolium confusum* WITH VARIOUS PERCENTAGES OF CO_2 PLUS SMALL QUANTITIES OF METHYL FORMATE

Per cent of CO_2	Hours required with atmospheres of—					
	CO_2 alone		CO_2 plus 5 mg. of methyl formate/L.		CO_2 plus 10 mg. of methyl formate/L.	
	50% kill	100% kill	50% kill	100% kill	50% kill	100% kill
100	6.3	10	1.8	4	—	—
75	12.9	20	2.4	6	—	—
50	27.7	44	3.6	8	1.8	4

SUPPLEMENTARY TESTS.—A number of tests were also conducted on the eggs and larvae of *Tribolium confusum* with atmospheres containing

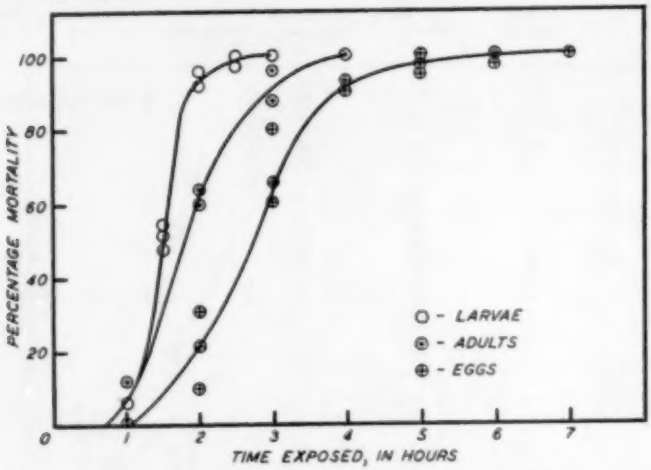

FIG. 77.—Toxicity of 50% CO_2, plus methyl formate at the rate of five milligrams per liter, to the egg, larval and adult stages of *Tribolium confusum* at 30°C.

50% CO_2, plus methyl formate at the rate of 10 milligrams/liter. The data presented in Table 5 and Figure 77 show that the larvae are killed by an exposure of 3 hours to this gaseous mixture, whereas 6 hours are required to kill the eggs (see Table 6 and Figure 77). The toxicity curve

of this mixture to the adult beetle is also shown in Figure 77, to facilitate comparison of the relative resistance of the different stages of this insect.

TABLE 5. TOXICITY OF ATMOSPHERES OF 50% CO_2 PLUS METHYL FORMATE (10 MG./LITER) TO THE LARVAE OF *Tribolium confusum* AT 30°C.

Hours exposed	Number of larvae	Number dead	Percentage mortality
½	50	0	0
½	50	0	0
1	50	2	4
1	50	3	6
1	50	3	6
1½	50	24	48
1½	50	26	52
1½	50	27	54
2	50	46	92
2	50	48	96
2	50	48	96
2½	50	49	98
2½	50	50	100
2½	50	50	100
3	50	50	100
3	50	50	100

TABLE 6. TOXICITY OF ATMOSPHERES OF 50% CO_2 PLUS METHYL FORMATE (10 MG./LITER) TO THE EGGS OF *Tribolium confusum* AT 30°C.

Hours exposed	Number of eggs	Number hatched	Percentage hatched	Percentage mortality[1]
1	50	38	76	0.0
1	50	40	80	0.0
1	50	41	82	0.0
2	50	41	82	10.2
2	50	33	66	21.4
2	50	29	58	31.0
3	50	18	36	60.6
3	50	14	28	65.6
3	50	8	16	80.3
4	50	4	8	91.2
4	50	3	6	92.6
4	50	3	6	92.6
5	50	2	4	95.2
5	50	1	2	97.6
5	50	0	0	100.0
6	50	1	2	97.6
6	50	0	0	100.0
6	50	0	0	100.0
7	50	0	0	100.0
7	50	0	0	100.0
7	50	0	0	100.0

[1]Determined by means of Abbott's formula (*1*) $\frac{X - Y}{X}$ (100) = Percentage mortality where X = per cent hatch in untreated lots, and Y = per cent hatch in treated lots.

As stated above under Methods, the tests reported in this paper were conducted in empty glass flasks at 30°C., no wheat or other adsorptive material being present. Consequently, when a product is present which will adsorb or absorb gases, or under practical fumigating conditions, the concentration of methyl formate in the gaseous mixture must be altered to overcome the factors of adsorption, absorption, lower temperature, etc.

Summary

1. Data are given on the toxicity of atmospheres containing 50, 75, and 100% of CO_2 to *Tribolium confusum* Duv.

2. Evidence is also presented to show that the toxicity of a given concentration of CO_2 (between 50 and 100%) may be markedly increased by the addition of small quantities of methyl formate.

3. The results obtained by the addition of this chemical (at the rate of 5 milligrams/liter) to the various percentages of CO_2 are as follows: (1) all of the beetles are killed in 4 hours with 100% CO_2 plus methyl formate, as compared with 10 hours for 100% CO_2 alone, (2) a complete kill in 6 hours with atmospheres containing 75% CO_2 plus methyl formate, as compared with the 20 hours required for the 75% CO_2–25% air mixtures alone, and (3) a 100% mortality in 8 hours with atmospheres containing 50% CO_2 plus methyl formate, as compared with the 44 hours required for the 50% CO_2–50% air mixtures without the methyl formate. When methyl formate is added at the rate of 10 milligrams/liter to the atmospheres containing 50% of CO_2 the beetles are killed in a period of only 4 hours, as compared with 8 hours when 5 milligrams/liter are added.

4. Additional data are included on the toxicity of atmospheres of 50% CO_2, plus methyl formate, to the egg and larval stages of the above insect. All of the larvae are killed with an exposure of 3 hours, whereas 6 hours are required to effect a complete kill of the eggs.

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METHOD FOR MAKING A GRASSHOPPER SURVEY

By ROBERT L. SHOTWELL, *Assistant Entomologist, Division of Cereal and Forage Insects, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture*

In order to be able to determine in advance the possibilities of grasshopper outbreaks and how much poisoned bait a county will need to control the infestations within its borders, surveys are made of conditions the preceding summer and fall. Before a survey can be made, it is necessary to have some means of measuring the degree of an infestation. Insect populations are usually classified as "normal," "light," "moderate," "heavy," and "very heavy." But if the average condition for a particular county or area is desired, such expressions must be reduced to a mathematical basis. Each observation can be rated with a number representing one of these categories, and from these ratings the percentage of infestation and the average for the county computed. In this paper it is shown how this is done and how the method can be used in determining costs of control.

EGG-LAYING HABITS OF GRASSHOPPERS.—It is important that the observers making a survey know the egg-laying habits of the grasshoppers in the region involved. Favorable breeding areas depend on the plant association and on the soil and topography of the place under observation, and vary according to the species of grasshopper. The known egg-laying habits of a few of the most important economic species in the Great Plains States are given briefly. If other species and other regions are involved, egg-laying habits under those conditions must be learned before an adequate survey can be made.

For egg laying, *Melanoplus bivittatus* Say will select the edge of a soddy roadside cut bank facing south, east, or west (preferably south); a ridge of sod in a headland, fence row, or ditch bank; or the roots of single-stalk plants, such as sunflowers, ragweed, or lambsquarters, and corn stubble. Seldom are eggs laid in open soil, unprotected by the roots of plants, and they are usually congregated.

M. differentialis Thos. is similar to *M. bivittatus* in egg-laying habits but shows a greater tendency to mass its pods in clumpy sod, such as patches of buffalo grass, laying its eggs in the crown of the grass.

Melanoplus mexicanus Sauss. egg pods are more scattered. In sandy-loam hummocks along fence rows they are somewhat congregated. In a stubble field they are found clinging to the roots of the stubs, being fairly well distributed over the entire field but often bunched around straw stacks. They are also found congregated underneath Russian thistles and around and between alfalfa plants.

M. packardii Scudd. prefers the open ledges of washed soil from a cut bank or blown sand of a fence row.

M. femur-rubrum DeG. eggs are usually found scattered in the same locations as those of *M. bivittatus*, *M. differentialis* and *M. mexicanus*.

Camnula pellucida Scudd. seeks breeding grounds in the short bunch grass of headlands, pastures, and roadsides, and deposits its eggs in the crowns.

Dissosteira carolina L. eggs are mostly found in open soil of washed dirt from a roadside ditch or cut bank or sand-blown fence row.

WHAT RECORDS ARE MADE AND HOW.—In making a grasshopper survey, the following factors must be taken into consideration: (1) The number of live hoppers per square yard in the fields or congregated in favorable breeding places, and (2) the number of egg pods per unit area or per given number of samples taken from breeding grounds.

The number of live hoppers per square yard, either in the field or congregated on breeding grounds, are simply estimated by the observer as he walks through a field. Before attempting to do this, it is well to lay out a square yard on the ground, stand off and look at it until the size of this unit area is fixed in mind. Numerous trials in which different workers have estimated separately for the same fields have shown that the counts checked very closely, and this justified the placing of considerable confidence in the accuracy of the method.

The egg pods are actually counted. Several methods of sampling for egg pods have been used. With *Melanoplus mexicanus* in a stubble field, a sharpened scoop shovel made over to hold one-half square foot of soil 3 inches deep is used. The samples of soil are taken along a linear foot of stubble, sifted through a wire screen of one-quarter inch mesh onto a canvas, and the egg pods counted. In searching for the eggs of *M. bivittatus* and *M. differentialis* laid in heavy sod, a small, sharp spade or shovel is used to cut out a clod about 4 to 6 inches square, and this clod is carefully examined. Ten of these samples are taken from the most favorable places. In some cases a square foot or square yard of sod has been actually shaved off and the pods have been counted. One-stalk plants are pulled and the pods counted, each plant being considered as one sample. In order to make comparable the counts of egg pods made under such varying conditions of sampling, it is important that the observer reduce all his counts to so many pods per square foot regardless of the size of the sample taken.

If no eggs are found at first, several trial examinations should be made in the vicinity and counts started when the breeding ground or infested field is located. In no outbreak have the hoppers hatched out of every square foot of ground. The pods are either congregated in some field or along some roadside, fence row, headland, ditch bank, etc. All possible places must be covered before one is satisfied as to his findings.

During the latter part of August and the first part of September, observations on the numbers of live hoppers per square yard in the field and congregated along the edges are of prime importance. For range land this is about the only basis for making a prediction. It is also helpful in locating likely places for egg laying for use in the subsequent egg survey. Later the number of egg pods per unit area is more important than the number of adult hoppers, because of natural mortality.

The method for making a survey of a county is as follows: Stops are made every 5 to 10 or more miles over the entire farming area, and, under some conditions, over range land as well. Each stop is located, numbered, and noted on a suitable road or county map. A record is kept of the findings at each place. Besides the number of hoppers and egg

pods, the record includes the type and condition of the field and vegetation where eggs are found, the extent of hopper damage, the dominant species, any information concerning parasites, predators, disease, etc., that might have a bearing on grasshopper abundance the following year, and finally, the rating as to the degree of infestation. The following type of form is used in recording the observations made at each stop:

GRASSHOPPER SURVEY

Person.....

Date.....193... Place.....State.....County.....

Field samples 1 2 3 4 5 Stop Rating

Egg Pods Per Sq. Ft. Crop

Egg Pods Per Sq. Ft. Roadside Adjacent Crop

	Wheat	Barley	Oats	Corn	Flax	Alfalfa	Sweet clover	Other crops
Hoppers per sq. yd. in fields of.....								
Hoppers per sq. yd. roadside next to.....								
Condition of field.....								
Condition of roadside.....								
Dominant species—field....	1		2			3		
Dominant species—roadside.....	1		2			3		

Remarks:

Rating the Stop. The five classes of infestations are rated as follows:

Normal Population. No damage or chance of damage; no control measures necessary..... 1

Light Infestation. Above a normal population, with probably no serious early damage but some chance of late damage to seed crops; population usually on the increase and control measures necessary to stamp out infestation..... 2

Moderate Infestation. Chance of early damage extending a rod or so into the fields; considerable late damage to seed crops and grain possible; control measures necessary, not only to stamp out infestation, but to protect crops from partial losses..... 3

Heavy Infestation. Chance of complete local destruction of crops; early concerted action on part of community or county necessary to protect crops..... 4

Very heavy infestation. Chance of widespread and total destruction of crops; county and State-wide organization for control measures necessary..... 5

These five degrees of infestation are rated on the basis of the numbers of live hoppers and egg pods found in the fields and along field margins and roadsides, both under irrigated and non-irrigated conditions, as shown in Table 1, decimals being used for those infestations which come in between the classifications.

TABLE 1. NUMBER OF LIVE HOPPERS AND EGG PODS WHICH DETERMINE THE RATING OF AN INFESTATION

Infestation rating		Live hoppers per square yard: In fields, Non-irrigated	Live hoppers per square yard: In fields, Irrigated	Live hoppers per square yard: At field margins and roadsides, Non-irrigated	Live hoppers per square yard: At field margins and roadsides, Irrigated	Egg pods per square foot: In fields, Non-irrigated	Egg pods per square foot: In fields, Irrigated	Egg pods per square foot: At field margins and roadsides, Non-irrigated	Egg pods per square foot: At field margins and roadsides, Irrigated
Normal.....	1	1	2	4	3	0.25	0.5	2	1
Light.....	1.5	1.5	3	6	4.5	0.375	0.75	3	2
	2	2	4	8	6	0.5	1	4	3
Moderate.....	2.5	3	6	12	9	0.75	1.5	12	7.5
	3	4	8	16	12	1	2	16	12
Heavy.....	3.5	6	12	24	18	1.5	3	24	18
	4	8	16	32	24	2	4	32	24
Very heavy...	4.5	12	24	48	36	3	6	48	36
	5	16	32	64	48	4	8	64	48

It will be seen that these numbers closely fit a geometrical progression. In a very heavy infestation there are approximately 16 times as many live hoppers or egg pods as in a normal infestation. But this does not mean that the bait requirements will be in the same ratio. The infestation ratings represent relative degrees of infestation; they do not pertain to the actual density of the population. For example, if there are three times as many egg pods per square foot in one field of 160 acres as in another field of the same size, it does not follow that three times as much bait will be necessary to obtain the same control in one as in the other. Since the same area has to be covered in both cases, the amount used per acre in the lesser infestation may be almost enough to take care of the heavier infestation in spite of the fact that one is only a third as great as the other. No doubt, the heavier infestation will spread out more and perhaps call for more applications and more bait, but not in arithmetical progression. This is true between any degrees of infestation, whether live hoppers per square yard or egg pods per square foot are being considered.

It must be remembered that Table 1 is but a guide and the observer should include other things, such as damage done, prior information, etc., in rating a stop. A survey is, of necessity, made rather hastily, and egg beds are not always easily found.

DETERMINING THE PERCENTAGE OF ACREAGE INVOLVED.—After a rating has been given to a stop, this rating is changed to the equivalent

TABLE 2. PERCENTAGE OF CROP ACREAGE INVOLVED CORRESPONDING TO DIFFERENT INFESTATION RATINGS

Degree of infestation	Rating	Percentage of crop acreage involved
Normal	1	0
Light	1.5	5
	2	10
Moderate	2.5	20 25 30
	3	40
Heavy	3.5	50 55 60
	4	70
Very heavy	4.5	80 85 90
	5	100

percentage of grasshopper-susceptible crop acreage involved. It has been found that with a normal infestation (No. 1) no acreage is involved from the standpoint of requiring control measures, whereas when a very heavy infestation (No. 5) is reached practically 100 per cent of the farmed area is involved. Experience has also shown that an infestation with a No. 2 rating involves 10 per cent of the crop acreage whereas the next higher rating, No. 3, involves 40 per cent. On the basis of this experience Table 2 has been set up to enable one to convert the infestation rating to the equivalent percentage of crop acreage involved. It does not follow a geometric progression, as does Table 1, and at best can only be an ap-

proximation, for one cannot be exact or follow mathematical principles when dealing with so complex a subject, which involves weather, cost of materials, attitude and experience of people, organization, availability of funds and materials, and last, but not least, the habits of the different species of the grasshoppers themselves. The method is nevertheless a good guide in estimating the extent of control measures necessary to combat outbreaks.

OBTAINING COUNTY AVERAGES.—If all the stops are distributed uniformly over the farmed area in a county, the observations at one of them are representative of a proportionate part of the farmed acreage. Thus, if 20 stops are made, the degree of infestation at one stop can be considered as representative of one-twentieth part of the farmed acreage. The average of the percentages of crop area involved at all the stops is therefore the percentage of the whole county. When the stops are not uniformly distributed over the farming area, and some parts of the county are not visited but information is obtained from county agents or other sources, the observer must then rate these parts proportionately to the total farming area of the county. For example, he may divide the county into 10 parts, and rate two tenths as 3, one tenth as 4, three tenths as 2 and four tenths as 1. From the percentage equivalents in Table 2 he obtains the average percentage for the whole county as follows:

	Per cent
$2 \times 40 =$	80
$1 \times 70 =$	70
$3 \times 10 =$	30
$4 \times 0 =$	0
	180

Average $(180 \div 10) = 18$

He may, of course, divide the county into any number of parts.

DETERMINING THE COST OF CONTROL.—When the percentage of crop acreage for the county has been determined, that percentage is taken of the total grasshopper-susceptible crop acreage for that county, as obtained from some source of crop statistics. This acreage is then figured to be poisoned at the rate of 10 pounds of bait (dry weight) per acre, which has been the accepted rate for calculating amounts of bran mash necessary. This amount, after being converted to tons, is multiplied by the cost per ton, to give the total cost of a control campaign to be expected under optimum conditions.

For example:

Total acreage of grasshopper-susceptible crops	200,000
Percentage of crop acreage involved	45
Acres of crops involved (200,000 × 0.45)	90,000
Pounds of poisoned bait required at rate of 10 pounds per acre (90,000 × 10)	900,000
Equivalent tons of poisoned bait	450
Predicted cost of control at $25 per ton (450 × 25)	$11,250

COMPILING STATE RECORDS.—From the information given for each county, State maps are made up showing each stop with its infestation rating and the degree of infestation of the infested areas indicated by different colors, as follows: White 1, green 2, yellow 3, red 4, and blue 5.

LIMITATIONS OF THE METHOD.—It must be remembered that the factors considered in making the survey are based on what can happen under the most favorable conditions the following spring. The ratings of the fall survey may be too high if unfavorable weather conditions the next year or egg predators cause a reduction in population. Furthermore, the factors used in determining the ratings in this paper are based on species and conditions found in the northern Great Plains States, and will probably have to be modified to fit species and conditions in other regions. Those familiar with conditions in their own States should be able to make such modifications. However, making stops throughout a county and numerically rating each stop will standardize the method and make the results comparable in all parts of the country.

SUMMARY.—A method of making a grasshopper survey is described whereby the extent of an infestation is reduced to a mathematical basis, so that it can be used for determining in advance the amount of materials and the cost necessary for control in a county or State. Grasshopper populations are usually classified as "normal," "light," "moderate," "heavy," and "very heavy." By giving to these categories ratings from 1 to 5, and rating each stop made in the course of the survey according to the degree of infestation found there, on the basis of the number of grasshoppers found per square yard and of egg pods per square foot, etc., it is possible to compute the percentage of infestation for that stop and the average percentage of crop acreage involved for the entire county. By taking this percentage of the total grasshopper-susceptible crop acreage of that county, taken from some crop statistics, the acreage to be poisoned is obtained. The amount of poisoned bait required is computed at the rate of 10 pounds (dry weight) per acre, and the cost figured from the prevailing prices.

AN IMPROVED MODEL OF AN AUTOMATIC INSECT FLIGHT TRAP DESIGNED TO PREVENT THE DESTRUCTION OF COLLECTED INSECTS BY WATER

By ROBERT A. FULTON, *Associate Entomologist*, and H. G. BERGEN, *Assistant Field Aide, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture*

An insect trap[1] which automatically receives and retains insects borne by moving air currents was developed at Twin Falls, Idaho, several years ago for the study of insect dispersion and flight associations. Several times during each year the collections in the glass receiving jar would be destroyed by water entering through the funnel arrangement

[1]R. A. Fulton and J. C. Chamberlin. A New Automatic Insect Trap for the Study of Insect Dispersion and Flight Associations. Journal of Economic Entomology, Vol. 24, No. 3, p. 757–761. June, 1931.

during periods of rainfall. These collections could usually be used for the identification of *Eutettix tenellus* or other characteristic species, but as far as providing material for permanent collections or determinations, they were most often worthless.

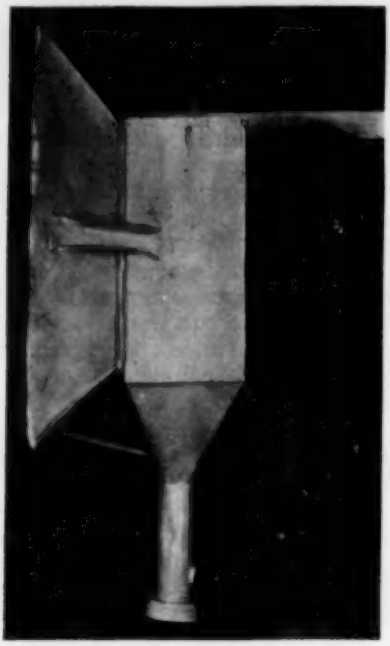

FIG. 78.—General view of modified wind vane trap designed to eliminate water in the collection bottle. The water outlet is shown just above the jar lid.

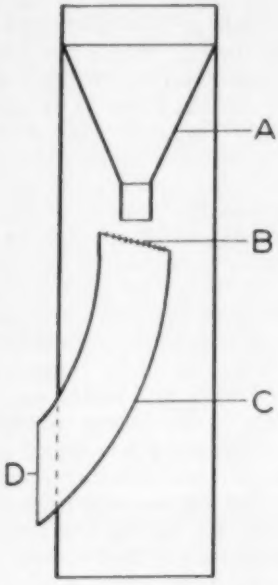

FIG. 79. — Diagram of construction of the water diverter showing arrangement of parts. Explanation of symbols is given in the text.

An apparatus has been devised wherein practically all the water entering the trap during a rain storm is by-passed to the ground, and insects entering the trap are retained by a wire screen and drop directly to the regular cyanide collecting jar. Figure 78 shows the apparatus attached to one of the wind vane traps, while Figure 79 shows a cross-sectional view and illustrates the mechanism of the by-pass for the elimination of water from the collection jar. The apparatus as shown is made of coke tin to fit directly on the funnel of the old trap. "A" is a small funnel soldered directly to the main tube to concentrate the droplets and prevent side splashing on the wire screen. "B" is a 20-mesh copper wire screen soldered to a ¾ inch copper tube "C." The wire screen is placed at a 20-degree angle, which permits the water to pass through without splashing

and at the same time tends to prevent insects from being retained on the screen. A Mason jar lid is soldered to the bottom of the apparatus. The copper tubing used for the outlet has served another purpose in sleet and snow when air temperatures were above freezing. Copper, being an excellent conductor of heat, melts the snow as fast as it falls on the wire screen.

This device has been used during the past season on 51 traps in the Twin Falls area. During this period three failed to function perfectly, but on examination it was found that too much acid was used in soldering and small holes had developed in the jar lids. The modified trap has functioned perfectly in all cases.

Traps equipped with this apparatus are particularly valuable when the station is located on a high range or in other inaccessible locations which make frequent or daily collections difficult or impossible.

FURTHER WORK SHOWING THAT PARADICHLOROBENZENE, NAPHTHALENE AND CEDAR OILS ARE INEFFECTIVE AS REPELLENTS AGAINST CLOTHES MOTHS

By W. S. ABBOTT, *Senior Entomologist*, and S. C. BILLINGS, *Junior Entomologist*, *Food and Drug Administration, United States Department of Agriculture*

Herrick (1), in a recent article in this Journal reviewing critically papers by Bottimer (2) and Billings (3) on the action of paradichlorobenzene, naphthalene and cedar oils as repellents against clothes moth adults and larvae, questions the accuracy of the conclusion of these authors,—in fact states that they are "erroneous" and "some form of technique very different from that used by the authors must be devised in order to obtain reliable results." In view of this criticism additional work was carried out, employing a technique which very closely approaches conditions that may exist in practical moth control work in the home.

Five tightly constructed boxes, three of approximately 10 cubic feet capacity (numbered 1, 2 and 3) and two of approximately 5 cubic feet capacity, (numbered 4 and 5), each provided with a hinged "door," were placed in a room 12′ 10″ x 7′ x 6′ 10″. These boxes were set on end to simulate closets and the "door" of each was opened for about three inches throughout the experiment. In Box No. 1 was placed a "drip machine" containing 100 cc. of cedar-wood oil, which slowly delivered the liquid into a porous wood container and thus furnished a constant volatilization into the air. Box No. 2 was provided with a similar "drip machine" containing 100 cc. of cedar-leaf oil. On the floor of Box No. 3 was placed 2.5 ounces of paradichlorobenzene, which was renewed occasionally to maintain approximately this amount throughout the test, and in Box No. 4, 2.5 ounces of naphthalene was placed. (The amounts of paradichlorobenzene and naphthalene used would have been effective as fumigants in killing clothes moth larvae had the box-

es been kept closed). Box No. 5 was left untreated as a check. On the floor of each box, and behind the chemicals to be tested, were placed two pieces of uninfested woolen goods. After twenty-four hours the fumes of the chemicals had thoroughly permeated the treated boxes, and at intervals during the following ten (10) days adult clothes moths (*T. biselliella* Hum.) were liberated in the room until a total of 88 had been released. The "closets" were not disturbed during this ten day period, but superficial examinations made daily showed adult moths in every one. The door of the room in which the boxes were placed was left open for about an hour each day, and the transom was slightly opened, so that there was no chance for the fumes to become sufficiently concentrated in the room to affect the moths. On the twenty-third day eggs and a heavy infestation of young larvae were found on the woolen material in every box, although the odor of the chemical present in each case was very pronounced in the box and on the cloth itself. The larvae appeared to be normal in every way and were feeding freely.

At the termination of the above test a similar test was started, using the same boxes but changing their relative positions in the room and the treatments in the individual boxes, the smaller boxes being used for the two cedar oils. In this test the naphthalene and paradichlorobenzene were suspended in cheese cloth bags near the top of the boxes. During the next three weeks 59 adult moths were liberated in the room. Observations made at intervals during this period showed adult moths in every box, and at the close of the test a heavy infestation of living, normal, moth larvae was found on the woolen goods in each box. In the first test the heaviest infestations occurred in the boxes where the cedar oils were used, and in the second the heaviest infestation was in the "closet" containing naphthalene and the lightest in the "closet" to which no chemical had been added. This, however, is not considered significant in this limited number of tests.

The fact that in these experiments the adult moths went into the treated closets as freely as into the untreated and deposited eggs which hatched, and that the larvae remained and fed on the flannel in all of the closets, shows conclusively that the chemicals used are of no value as clothes moth repellents.[1]

These tests, made under conditions which closely approach those that would be found in the average home, fully substantiate the previously published conclusions by Bottimer (2) and Billings (3).

The value of cedar chests against moths has been carefully investigated by Back (4), and the following quotation from his bulletin indicates his observation as to their repellent action.

> "Cedar chests exert no noticeable effect upon the adult moth or miller, the parent insect, which does no damage to clothing but which may lay eggs from which hatch the destructive larvae, or worms. Moths that run or fly into chests, when open, may live as long as two weeks or even a month, and lay many fertile eggs."

[1]This work was not designed to show the fumigation value of the materials used.

The reference to "Moths that run or fly into chests, when open" shows the absence of repellent value. Back also states:

> "Although cedar chests may be regarded as protectors against clothes moths, attention is called to the fact that a chest of ordinary wood, if as tightly constructed, would be just as effective, provided the clothing were as thoroughly cleaned, brushed, and sunned, and from 1 to 2 pounds of good grade naphthalene were packed within."

There has been a rather wide-spread misconception on the part of the public that paradichlorobenzene, naphthalene and cedar-wood oil will repel or drive away moths, but this is not, as far as can be ascertained, based on any published or unpublished experimental data. This erroneous idea has been capitalized extensively by many manufacturers who have sold as "moth repellents" products which actual tests have shown to be of no value for this purpose. The consumer is entitled to protection against these false and misleading claims, and the Food and Drug Administration of the U. S. Department of Agriculture has issued notices to the trade that paradichlorobenzene (5) and naphthalene (6) are ineffective as repellents for clothes moth adults and larvae and that the sale of these products under representations that they will repel moths is a violation of the Federal Insecticide Act.

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Scientific Notes

Does Laundering Impair the Efficiency of Mothproofing with Sodium Fluosilicate? Inquiries are frequently made as to the permanency of mothproofing with sodium fluosilicate, carpets and other fabrics when sent to the laundry. In order to gain some information on this point, a piece of mohair was mothproofed by dipping it in a saturated solution of sodium fluosilicate. Upon drying the mohair was cut up in three parts. One piece was dry-cleaned, and another piece was washed with soap and water. On October 4, carpet beetle larvae were placed on the three pieces, as well as on an untreated piece.

By November 11, all of the larvae were dead on the piece that was mothproofed, and also on that dry-cleaned. On the piece that was mothproofed and washed with soap and water, the larvae lived as long as December 3, while on the untreated portion all were alive.

As is well known, sodium fluosilicate is insoluble in organic solvents, and it is, therefore, not surprising that dry-cleaning does not impair the efficiency of the mothproofing. Even though sodium fluosilicate is soluble in water, washing with soap and water did not destroy the mothproofing qualities, although it did slow up its action.

The above data would be even more true for clothes moth larvae, for they succumb much more readily than the hardy carpet beetles.

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Toads in the Control of Auto-Camp Insects. The night of July 16 to 17, 1934, was spent at an automobile tourist camp at Washington, in Utah's "Dixie," near St. George. Insects in abundance were attracted to the electric lights, causing annoyance by biting people and lighting upon their faces and arms which occurred even inside of the cabins. Toads were noted to be very abundant on the camp grounds; 17 specimens were collected about midnight and preserved. A microscopic examination of the stomach contents was subsequently made in the laboratory. Recognizable contents of 13 *Bufo woodhousii* Girard stomach's consisted of 3 Orthoptera, 1 nymphal and 2 adult grasshoppers; 8 Hemiptera, including 1 Nabidae and 4 Lygaeidae; 1 Homoptera, a leafhopper; 148 Coleoptera, including 59 Carabidae, 23 Chrysomelidae, most of which were asparagus beetles, 41 Elateridae, one being a larva, 3 Tenebrionidae, 3 Meloidae, 12 Scarabaeidae, 2 Coccinellidae, and 1 Dermestidae; 3 adult Lepidoptera; 271 Hymenoptera, of which 1 was a honey bee and the rest ants; 5 centipedes; 5 sowbugs; 18 spiders; and 7 plant fragments. Stomachs of 2 *B. cognatus cognatus* (Say) contained 1 Homoptera, a leafhopper; 6 Coleoptera, including 3 Carabidae, and one each of Scarabaeidae, Meloidae and Melydridae; 21 Hymenoptera, ants; and 1 plant fragment. Stomachs of 2 *Scaphiopus hammondii* Baird contained 2 Coleoptera, 1 an Elateridae; 1 Lepidoptera; 3 Hymenoptera, ants; and 1 spider.

G. F. KNOWLTON and C. F. SMITH, *Utah Agricultural Experiment Station*

Applications of Atomized Oil Sprays to Certain Truck Crop Insects. Atomized phytonomic oil sprays tested in 1933 and 1934 at Racine, Wisconsin showed in several instances that they were very effective in controlling certain insects infesting truck crops. Undiluted oils containing steeped Derris root, naphthalene, and dilute oil extracts of pyrethrum compared favorably with aqueous sprays for controlling onion thrips. A pyrethrum-oil combination containing 1.1 mg. of pyrethrins I and II per cc. of oil, applied at the rate of 3 to 4 gallons per acre, was very efficient in controlling the potato leaf hopper. Following the first applications of pyrethrum sprays to heavy leaf hopper-infested area of Triumph potatoes, as high as 210 dead leaf hoppers were found under a single vine. The increased yield of tubers from one plot was 42% over similar vines dusted with Bordeaux. No foliage injury was apparent following the application of these oils and sprayed potato foliage frequently made a more vigorous growth and remained greener for a longer period of time.

A completely refined light hydrocarbon distillate having a 30–35 viscosity and an unsulphonatable residue above 97 was used as the carrier for the insecticides. Machinery employed for applying the sprays consisted of a two-stage compressor unit driven by a 3 h. p. air-cooled gasoline engine. The entire unit weighed less than 250 pounds including tanks, boom and insecticide, and could be therefore mounted upon a light conveyor for field use. A three-row boom with nine nozzles, three nozzles to each row, was assembled for spraying potatoes. The effectiveness of these sprays was greatly increased by using a hood and a canvas drag which aided in keeping the concentration of mist about the plants.

Tests to date with concentrated sprays are of a preliminary nature but it is hoped that further investigations with improved equipment will give more conclusive results.

T. C. ALLEN, *University of Wisconsin*

The Effects of Attack by *Pissodes terminalis* Hopping on Lodgepole Pine in California. Hopping (Can. Ent. 52: 132–134, 1920), when describing *Pissodes terminalis* as new, gave fairly complete notes on the distribution of the species as well as the

type of injury caused by its attack. Except for a note by Keen (Calif. Dept. Nat. Res. Bul. 7: 70, 1928) no further mention of the species or of the injury caused by it is to be found in the literature.

Work of the lodgepole terminal weevil recently has been found to be abundant on immature trees in lodgepole areas of the Sierra Nevadas from Yosemite north into Oregon. Hopping has, in addition, reported it farther to the south in the Kings River and Kern River basins. The damage caused by this species is relatively unimportant in many of the areas in which it may be found, particularly in uneven-aged stands in which the mature trees shade the natural reproduction that is to be found in small openings in the forest cover. Serious damage does occur in even-aged stands of reproduction and poles up to 25 feet in height, particularly when the individual trees are rather widely spaced. Three such areas, i. e. Medicine Lake in Siskyou County, Hat Creek in Shasta County, and an area near Chester in Lassen County, have shown extreme and abundant injury that has affected the growth and form of the trees.

Injury caused by *Pissodes terminalis* in lodgepole pine is similar, in some respects, to that caused by *P. strobi* in eastern white pine. However, the details of the habits and seasonal histories of the two species are different. The adults lay eggs in the terminals, usually in the current season's growth above the last whorl of branches. Oviposition probably occurs late in June or early in July. Occasionally tips of branches may be attacked, particularly if they are codominant. Several larvae develop within the pith of the terminal and pupation occurs in small cells constructed in that substance. The infested portion withers and dies.

Minimum injury suffered by the young trees appears to be the occasional loss of the terminal growth of the year of attack. The maximum injury that has been found consisted of successive attacks on primary and secondary terminals, resulting in the formation of bushy, misshapen, multiple-boled trees. One such tree, not over 10 feet in height, was found to have suffered five attacks in seven years and, as a result, formed two and possibly three codominant, though lateral, boles. In heavily infested areas successive attacks on individual trees are common, and the abnormal form resulting from them changes the characteristics of the stands considerably. In the uneven-aged stands the occasional destruction of a leader does not change the general appearance of the stand.

It is worthy of note that all trees that have been found to be heavily infested range from 6 to 25 feet in height. In addition, the trees are relatively widely spaced and the stands are even-aged replacements following catastrophic disturbances. Barkbeetle epidemics and fire were followed by the growth of even-aged material at Chester and Medicine Lake while a volcanic disturbance was the cause of the even age of the material at Hat Creek.

In all three areas of heavy infestation, mature trees at the margins of the younger stands show the effects of previous attacks. A direct relationship between the abnormal form of mature trees and terminal weevil attack could not be determined. However, the fact that many mature trees have a bushy form and several codominant boles indicates that injury, caused by the terminal weevil when the trees are young, may be the reason for many of the deformities so prevalent in certain mature lodgepole stands in California.

K. A. SALMAN, *Associate Entomologist, Berkeley, California*

JOURNAL OF ECONOMIC ENTOMOLOGY

OFFICIAL ORGAN AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

APRIL, 1935

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A. A. A. S. Winter meetings, December 1935, St. Louis; December 1936, Washington; December 1937, Indianapolis, Ind. Summer meetings, 1935, Minneapolis; 1936, Rochester, N. Y.; 1937, Denver, Colo.

Are there opportunities in economic entomology? An appropriation of over $2,350,000 was secured from Congress for grasshopper control work in the Northwest. Over 15,000,000 acres in 18 states were threatened with widespread devastation. More than 75,000 tons of grasshopper bait were prepared and distributed over this vast area and the dramatic control of the hordes of grasshoppers resulted in a saving in excess of $50,000,000. There was a carefully worked out educational campaign, more than 1000 meetings being held in the two Dakotas. A general appreciation of the situation with earnest cooperation of all agencies saved the day. The wonderful record of Minnesota the preceding season was a great help in extending operations to the much greater area. There are surely opportunities in economic entomology. It is necessary that there be organization as well as specialization. The practical application of knowledge is power.

There were innovations in the program of the Pittsburgh meeting, and these are reflected in the published proceedings. The committee appointed to cooperate with the Secretary arranged for a symposium on international entomological problems, and these papers depicted, in a comprehensive way, the problems of Canada, Mexico and the United States, in relation to each other. It can hardly result in other than a clearer conception of the entire quarantine situation. In addition, the committee in cooperation with the Secretary arranged for a group of invitation papers. These are a series of comprehensive papers, published so far as they have become available, in this issue, and deal with the grasshopper problem, mosquito control work, the chinch bug situation, the corn borer problem, and the entomological phases of the Dutch elm

disease. All of these are of outstanding importance, and the assignment of them to a special place on the program presumably meets with general approval. The series of papers on the codling moth, both those presented at the meeting of the Eastern Branch and before the general Association are along the same line, though somewhat different in their nature. The large number of papers presented before the Association, its branches or sections, makes it probable that more rather than less direction, so far as the various programs are concerned, is desirable, if the organization is to render maximum service to its membership. There naturally will be differences of opinion as to subjects which should be emphasized and the methods employed. This can not be avoided. There are physical limitations as to the time which can be used for the various meetings and available resources restrict the amount of material which can be printed. A tacit recognition of these limitations and the wholehearted cooperation on the part of the members with the Secretary and the program committee will do much to lessen difficulties or disagreements in the future. It is assumed that the effort to make the meetings more serviceable will be continued and it is probable that the membership will have additional opportunities to cooperate in the achievement of this most desirable end.

Review

The Cotton Worm in Egypt, by IBRAHIM BISHARA. Extrait du Bulletin de la Société Royale Entomologique d'Egypte, Année 1934, Fascicule 3, pp. 288–420, with 3 colored plates, 8 halftone plates, 7 text illustrations, 31 diagrams, 23 tables, 4 maps, 2 charts and 3 appendices

Not *Alabama argillacea*, but *Prodenia litura* is the cotton worm of Egypt—one of the most troublesome and best investigated with which the *fellah* must deal. While it feeds on a great variety of plants such as *barseem* (Alexandria Clover), alfalfa, maize, etc., these crops are largely *shita* (winter) ones and, as *Prodenia* is most in evidence in midsummer, cotton is the crop which is most seriously affected. Altho it has received the attention of farmers and scientists for six or seven decades, *Prodenia* is today exceeded in importance as a cotton pest only by the bollworms, *Platyedra gossypiella* and *Earias insulana*. Under certain conditions, particularly in the Delta of the Nile, it is yet quite capable of enormous damage—as witness the serious outbreak of last year—first by defoliating the cotton plants and finally even surpassing boll worm ravages by destroying flower buds and young bolls.

In a remarkably well presented and illustrated publication characteristic of those sponsored by the Royal Entomological Society, whose Bulletin should be far better known outside of Egypt—the excellent papers of H. Priesner on Thrips and monographs on Dipterous families by H. C. Efflatoun Bey are some of the more recent testimonials to this fact—Bishara has included the results of years of patient research on *Prodenia* life history and control and handled an astoundingly complex mass of accumulated data in such a way as to clarify many obscure phases of both biology and repressive measures.

The early literature of *Prodenia* in Egypt is decidedly scanty. Lascaris' report on his investigations in 1880 is probably the first serious contribution to it. The present paper brings the whole subject up to date and affords us some interesting glimpses into the psychology of the *fellah* as well as into the extraordinary web of government regulations which has been built up during decades of official attempts at control. It is interesting to know that early control legislation provided for the employment of

corvée (forced) labor—one of the principal bones of contention during de Lesseps' construction of the Suez Canal.

Bishara gives a good review of the geographical distribution, status and host plants of *Prodenia* in other countries as well as Egypt and a most thoro consideration of its biology in the latter, as well as its natural enemies. His handling of the historical and legal phases of control measures is particularly fascinating and shows clearly how the efforts of the earlier Control Commissions (1883–85) were handicapped by the very general belief amongst the *fellahin* that the worms originated spontaneously and even by the religious conviction, similar to that in many parts of India today, that it was sinful to attempt to mitigate a scourge sent by Providence. The "Barseem Law," prohibiting the watering of the Alexandria Clover crop after 10th May of each year, to prevent intense breeding of *Prodenia* therein just prior to the normal occurrence of the insect in cotton fields, was passed in April, 1913, and, while Bishara considers that the provisions of the law if enforced might be of great usefulness to the cotton planters, he points out the conflicts of interests and tedious procedures which make its enforcement highly improbable.

The laws controlling the forced collection of egg-masses—the most common repressive measure employed in the country—are also discussed at length and a most humane and practical consideration of this effective, but back-breaking method is included therein. This leads up to chemical control, which is in its infancy in Egypt and presents many interesting, if not insuperable, social and economic obstacles. Another aspect of chemical control measures, which has not been unknown in other countries, is the fact that the use of insecticides may embody the risk of checking *Prodenia* ravages at the cost of encouraging another serious pest, the cotton aphis, *A. gossypii*. Bishara's experiments seem to show that if the amount of calcium arsenate applied does not exceed four kilograms per *feddan* (practically the same area as an acre) and if this is evenly applied, this danger may be avoided.

ARTHUR H. ROSENFELD, *Ministry of Agriculture, Giza, Egypt*

Current Notes

Dr. S. W. Bromley returned April 15 to his position of Assistant Entomologist at the Bartlett Tree Research Laboratories, Stamford, Conn.

A digest of field studies at the Belleville Ontario Parasite Laboratory indicate very definitely that the oriental fruit moth is now but a minor pest in sections of Ontario where the parasite *Macrocentrus ancylivora* is well established.

The Insecticide Society of Washington was organized in October 1934 to promote personal and scientific contacts among Federal and State chemists and entomologists who are concerned with the development, testing, or application of insecticides. Meetings are being held at present on the third Wednesday of each month at the laboratory of the Bureau of Entomology and Plant Quarantine at Takoma Park, Md. Federal and State workers visiting Washington are invited to attend these meetings.

In carrying out investigations to discover the possibility of foreign insects entering Canada in packaging and packing material other than plants and plant products, the following interesting interception was made by Entomological Branch inspectors under the Destructive Insect and Pest Act. Both adults and living larvae of *Scolytus intricatus* Ratzeb., a bark beetle, were found under the bark of split ash poles used as supports in containers for shipping china. The shipments concerned originated in England and were consigned to several Canadian firms. Inspectors in various districts made interceptions presumably coming from the same source. This bark beetle is widely distributed in Europe and is known to infest *Fagus*, *Carpinus*, *Quercus*, *Ulmus*, and *Populus*. As this species is also recorded as attacking elms, it might serve as a vector for the Dutch elm disease. The inspectors in Toronto state that had not these crates been destroyed they would have been used to construct a rustic fence.

Horticultural Inspection Notes

A second revision of the Pennsylvania Potato Wart quarantine No. 19 has been issued, effective April 1, 1935. According to R. H. Bell, Director of the Pennsylvania Bureau of Plant Industry, only one change is made in the previous regulations, that being the removal of restrictions relating to planting of immune varieties of potatoes in Jackson and Schuylkill counties. Soil treatment for the eradication of wart will be applied this spring, he states. All other restrictions remain the same as the previous regulations.

The Texas Department of Agriculture, according to J. M. Del Curto, Chief, Division of Plant Quarantines of that state, will accept Narcissus bulbs having state certification and inspection of bulbs as nursery stock, whenever such stock is shipped into Texas, with the understanding that it will be subject to destination inspection by their authorized agents whenever they receive a specific request by any firm or individual.

According to an announcement made by the California Department of Agriculture, their intrastate narcissus bulb quarantine has been revoked, following the revocation of the Federal Quarantine 62, pertaining to narcissus bulb pests, and these bulbs hereafter will be admitted from other states subject to the same destination inspection requirements as other nursery stock.

A new hybrid barberry bush, *Berberis mentorensis* Ames (MS), is being offered to the public by an Ohio nursery under Plant Patent No. 99. Supplement No. 1 of PQCA 320 (Second Revision) has been issued, adding this shrub to Group B under the Federal Quarantine No. 38, in consideration of experimental work which shows that this new patented hybrid is resistant to Black Stem Rust of grain. This barberry can, therefore, be shipped into or between the protected states, provided it complies with all regulations, including the restriction that a Federal permit must be attached to each shipment into said protected states.

The Federal Domestic Sugarcane Quarantine No. 16 was revised, effective January 1, 1935. According to Lee A. Strong, Chief, Bureau of Entomology and Plant Quarantine, the revision of this quarantine was desirable to bring it into conformity with the recently-revised foreign quarantine No. 15, and thus to provide control over the domestic movement of bagasse and other sugarcane materials from Hawaii and Puerto Rico by permitting such movement only under conditions which the department believes to be safe.

In carrying out the enforcement of the alfalfa weevil quarantine, L. M. Gates, Entomologist of the Nebraska Department of Agriculture and Inspection, reports the arrest of three parties for transporting hay from Goshen County, Wyoming, into Nebraska in violation of their statutes. One of the parties was fined $100 and costs and required to move the hay back into Wyoming. The other two parties, at the time this report was made, had not yet been arraigned.

Quarantine Proclamation No. 2 issued by the State Department of Agriculture of California, pertaining to the chestnut bark disease, became effective on January 19, 1935. According to A. C. Fleury, Chief of the Bureau of Plant Quarantine of that state, this is a revision which places chestnuts and chinquapins under quarantine, in addition to plants and cuttings of the chestnut and chinquapin tree from Eastern states, based on advice received from the Federal Department of Agriculture that such nuts may act as carriers of this disease. It is noted that foreign shipments in their original unopened containers will be granted entry into the state.

Report of the death of Vincent F. Peterson, Plant Pathologist for the Division of Insect Control and Nursery Inspection for the Minnesota Department of Agriculture Dairy and Food, has been received from Professor A. G. Ruggles, State Entomologist of that department. Mr. Peterson died February 14 after a brief illness. He was born in Balfour, North Dakota in 1902. Since graduating from the University of Minnesota and completing post-graduate work at that institution, he was employed as Plant

Pathologist until the time of his death. He was well known for his splendid work among the Minnesota fruit growers and nurserymen throughout the state. During recent years he has, in addition to his state duties, been in charge of the transit inspection work at St. Paul for the Federal Bureau of Entomology and Plant Quarantine. He is survived by his wife, Verna L. Peterson, and his three-year old daughter, Vee Peterson.

A conference of officers of the Entomological Branch, Canada Department of Agriculture, was held in Ottawa, November 26–30, 1934, under the chairmanship of the Dominion Entomologist, Arthur Gibson. The mornings were devoted to general sessions and the afternoons to meetings of the various Divisions. Officers of the Plant Inspection Service attending the conference, included the following from headquarters: Messrs. L. S. McLaine, W. N. Keenan, S. H. Short, P. N. Vroom, M. R. Baker, N. D. Cass; also, A. K. Gibson, Halifax, Mr. A. Finnamore, Saint John, N. B., Mr. L. R. Gagnon, Quebec, P. Q., Mr. W. Ryan, Montreal, P. Q., Mr. N. Beaudoin, Montreal, P. Q., Mr. H. A. U. Monro, Montreal, P. Q., Mr. W. A. Fowler, Toronto, Ont., Mr. R. W. Sheppard, Niagara Falls, Ont., Mr. W. R. Lapp, Windsor, Ont., Mr. C. A. S. Smith, Winnipeg, Man., Mr. P. C. Brown, Estevan, Sask., and Mr. H. F. Olds, Vancouver, B. C.

The Canadian government was represented by Dr. H. T. Gussow, Dominion Botanist, Mr. D. R. Cameron, Associate Director of Forestry and Mr. L. S. McLaine, Chief, Division of Foreign Pests Suppression, at the conferences called by the Bureau of Entomology and Plant Quarantine and held in Washington, D. C., December 3–5, to consider the white pine blister rust situation, the gipsy moth and Dutch elm disease.

Severe storms on the Pacific coast which occurred in January, caused considerable damage to the Canadian government Inspection Station at Vancouver, the low temperatures causing damage to the heating apparatus in the building.

The annual meeting of the Apple Maggot Advisory Committee was held in Ottawa, on February 20, 1935. The following members of the Dominion Department of Agriculture were present: Messrs. Arthur Gibson, Dominion Entomologist, Chairman; L. S. McLaine, Chief of the Division of Foreign Pests Suppression, Secretary; Lt.-Col. R. L. Wheeler, Fruit Commissioner; Messrs. W. A. Ross, Entomological Laboratory, Vineland Station, Ont.; C. E. Petch, Entomological Laboratory, Hemmingford, P. Q.; C. M. B. Maxwell, Entomological Laboratory, Fredericton, N. B. The various provinces were represented as follows: Nova Scotia—Mr. V. B. Leonard, Chairman, Nova Scotia Apple Maggot Control Board, Mr. A. D. Pickett, Provincial Entomologist;—Quebec—Mr. Georges Maheux, Provincial Entomologist, Mr. W. J. Tawse, Secretary of the Quebec Pomological Society;—Ontario—Professor Lawson Caesar, Provincial Entomologist, Mr. R. Harry Crews, Representing the Ontario Fruit Growers;—British Columbia—Mr. W. H. Robertson, Provincial Horticulturist.

The Oregon quarantine relating to the potato tuber moth (No. 13) was amended on December 26 to apply to the Territory of Hawaii. The European corn borer quarantine of the State of Virginia was extended on November 7 to include Maryland and Delaware, according to an informal announcement of November 16 of the State Entomologist of Virginia.

Under an extension of the Hawaiian quarantine relating to the citrophilus mealy bug, the maritime mealy bug, and the so-called bean thrips, approved by the Governor on October 14, freight shipments of citrus fruits and persimmon fruits from Arizona and California must be fumigated. The requirement applies to citrus fruits during the period November 1 to March 31 and to persimmon fruits throughout the year. The quarantine formerly related only to such fruits from California.

A North Carolina permit is no longer required for shipping nursery stock into that state, the plant pest regulations having been revised on July 15 to exclude this requirement. The duplicate nursery inspection certificate is required to be mailed to the North Carolina Department of Agriculture and a copy attached to each shipment.

Recent quarantine action on the part of the Bureau of Entomology and Plant Quarantine at Washington, with reference to shipments interstate includes: (1) Placing a quarantine relating to the Dutch elm disease (effective February 25) which prohibits the movement from the regulated area in New York, New Jersey, and Connecticut of elm trees and parts, of logs and cordwood of such plants, and of lumber and containers manufactured from such plants unless the wood is entirely free from bark; (2) amending the black stem rust quarantine, effective February 20, exempting from restriction the movement of Mahonia cuttings when shipped for decorative purposes; (3) amending the white pine blister rust quarantine, effective March 15, by adding Minnesota to the list of states for which a control-area permit is required in shipping currant and gooseberry plants; and (4) revoking Federal quarantine No. 62 relating to the interstate movement of narcissus bulbs. This revocation was effective on April 1.

Mr. W. C. Hanson has been appointed deputy inspector in the Division of Insect Control, Nursery and Apiary Inspection. At the present time Mr. Hanson is employed by the Bureau of Entomology and Plant Quarantine on transit inspection of material moving in domestic commerce and inspection of plant material arriving in the mails at St. Paul customs mail bureau from foreign countries.

A law enacted at the present session of the Minnesota legislature provides that counties may appropriate funds for the control of insect pests, rodents, bee diseases or plant diseases when recommended by the Commissioner of Agriculture. Such funds shall be expended according to plans designated by the State Entomologist and persons appointed to carry on such work shall be those having the qualification deemed necessary by the State Entomologist. The act further provides that all owners of land infected with dangerous insects or plant diseases be compelled to co-operate under rules and regulations promulgated by the County Board for the eradication of such pests or diseases.

Eighteen entire counties of northeastern Minnesota and a portion of two others, together with nursery eradication zones and control areas around two Minnesota areas are included in an order recently issued by the Conservation Commissioner and State Entomologist as their Blister Rust control area. In effect, this act provides that no currant or gooseberry plants can be shipped into these areas without first obtaining a permit from the Commissioner of Conservation.

The twelfth annual meeting of the Central Plant Board was held at Urbana, Illinois on the 27th and 28th of February. Running concurrently with the National Codling Moth Conference and Central States Entomologists which met just prior to and following this meeting the attendance was unusually large. Twelve of the thirteen states included in this group were represented, in addition to visitors from several other states and the Federal Department of Agriculture. Among the representatives of the Federal Bureau of Entomology and Plant Quarantine were Lee A. Strong, L. H. Worthley, S. A. Rohrer, S. B. Fracker, and E. R. Sasscer. A report on the National Plant Board was made by Professor George A. Dean, Central states representative and Vice-chairman of that board. The most important business transacted by the group was the revision of the alfalfa weevil quarantine to meet the present emergencies. Representatives from Nebraska and Idaho interested in selling and shipping alfalfa hay were in attendance. Other important topics discussed at the general meeting included White Pine Blister Rust control and barberry eradication, the Dutch elm disease, plant quarantine in connection with the entry of foreign plants, strawberry certification, crown gall of raspberries, need for uniformity in regulations, current violations of nursery inspection laws, reciprocity laws for interstate shipment of nursery stock and the phony peach disease situation.

In order to get first-hand information on the southern-most insect eradication problems of the country, the National Plant Board met in Miami, Florida, with the Southern Plant Board during the week of February 4. The wild cotton eradication work at Cape Sable being conducted by the U. S. Department of Agriculture and the Florida Plant Board proved most interesting. Stalks of cotton 25 feet high bearing blooms and opened balls in February are abundant in the swamp. Some of it is infested with the Pink bollworm and the eradication was observed by the eight board members to be conducted thoroughly although under adverse conditions.

At Key West the board studied the eradication by spraying and clean-up work of two species of fruit flies, and of the black scale. These pests constitute a threatening menace to semi-tropical horticulture. International airports were again recommended to the National Committee on Airways, so that planes arriving from foreign countries might be grounded for inspection on the border as a means of preventing the introduction of plant pests from foreign countries.

The National Board saw fit to approve the revoking of Federal Quarantine No. 62 referring to narcissus bulb importation, since it found that the action of the Secretary of Agriculture was in line with its previously expressed "Principles of Quarantine".

It is likely that the National Plant Board will call a conference of all state plant quarantine officers to be held in July, 1935 in Chicago. The conference will be held to consider plant quarantines in general.

The National Plant Board is composed of eight representatives, two of which are elected by each of the four regional plant boards. It was organized in 1925. Twelve meetings have been held, and a total of 75 subjects relating to plant quarantine work and insect and plant disease eradication have been under consideration by the Board one or more times.

W. C. O'Kane, Durham, N. H., is Chairman of the Board. Other officers are G. A. Dean, Manhatian, Kansas, Vice-Chairman and R. W. Leiby, Raleigh, N. C., Secretary. Other members are, J. F. Adams, Newark, Delaware, E. L. Chambers, Madison, Wisconsin, M. S. Yeomans, Atlanta, Ga., A. C. Fleury, Sacramento, California, and George M. List, Fort Collins, Colorado.

Preoviposition Period of the Apple Maggot Fly, *Rhagoletis pomonella* Walsh, in Eastern New York. *Rhagoletis pomonella*, in common with many of the Diptera, undergoes a postpupal period of development of the ovaries before egg deposition begins. The exact length of this period under normal conditions has not been determined, chiefly because the species does not lend itself readily to rearing methods, and the data obtained by field observation, at best, are approximate.

The writer has completed a series of observations on flies reared under normal conditions, using the following procedure: Flies, removed daily from emergence cages, were held at a low temperature until inactive and then marked with metallic radiator paint in the manner described by Phipps and Dirks (Jour. Ec. Ent. 25: 576–582, 1932). They were then quickly liberated in one of a group of isolated, unsprayed apple trees bearing a good crop. By the use of several colors of paint, flies of different age groups could be distinguished. Daily liberations were continued for fifteen days. Each tree in the group was then examined and as many flies as possible were captured in vials. A sheet was then placed beneath the tree, which was thoroly dusted with a strong nicotine-lime dust, and a number of flies recovered from the sheet. The percentage of recovery was small for each of the three years during which observations were made. The recovered flies were then taken to the laboratory where the females were dissected and the ovaries examined.

Flies one to three days old were found to show no development. After four to six days in the field, the ovaries of some individuals were beginning to increase in size, while those of flies seven to eight days old were generally considerably enlarged, with great variation between individuals. Most flies nine to ten days old were mature and one individual of this age group was observed to oviposit before being captured. All flies twelve or more days old were mature.

It may be concluded from the above data that the average preoviposition period of *Rhagoletis pomonella*, under normal conditions in this area, is nine to ten days in length, with a probable minimum of seven to eight days.

R. W. Dean, *Hudson Valley Fruit Investigations Laboratory, New York Agricultural Experiment Station*